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THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY HISTORY SPACE

INSIDE

ATTACK OF THE VIKINGS

10 SENSES YOU NEVER KNEW YOU HAD

WONDERS OF YELLOWSTONE

Wild beasts, 100ft geysers & the supervolcano that could destroy America

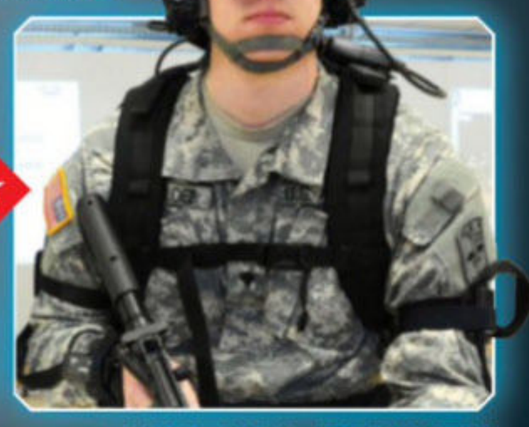
▽THERMAL & NIGHT VISION GOGGLES

▽ADVANCED BLOOD CLOTTING FABRIC

▷SMART GUN

▷NANO-CERAMIC ARMOUR

◁WEARABLE COMPUTERS



TOMORROW'S ARMY OF SUPER SOLDIERS

△EXOSUITS

△VIRTUAL REALITY TRAINING

HOW TECH IS TRANSFORMING THE FUTURE OF WARFARE

△BATTLEFIELD DRONES

MULTI-MILLION DOLLAR MOTORS

Faster, harder, stronger: Inside the most luxurious rides on the planet

+LEARN ABOUT

- TREATING WATER
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ISSUE 74

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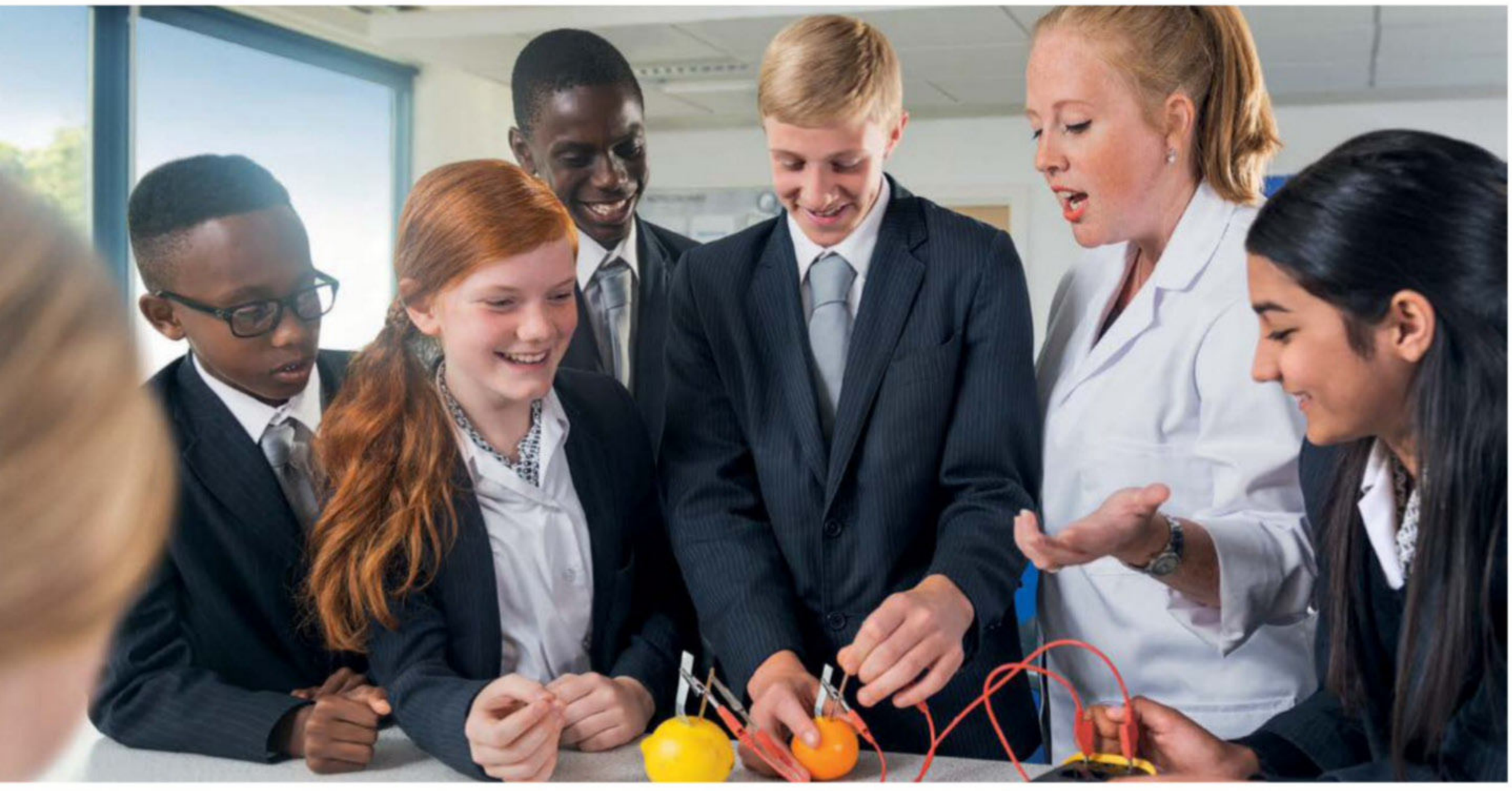

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ISSUE 74

WELCOME

The magazine that feeds minds!

Page 70
Could there be life on Titan?

Science was one of my favourite subjects at school. You could tell by looking at my timetable; each lesson was decorated with stars. How else do teenage girls express their love for something, if not in glittery gel pen? These days I prefer biro and indulge my interests by making this magazine. But school days never really leave you. They're such a key part of growing up and Pixar's *Inside Out* will reawaken those memories in every adult who watches it.

The movie takes place inside a young girl's mind (the so-called Headquarters), where characters called the Emotions help her deal with life's challenges. It reminded me of our feature – The 'Other' Senses – where we shine a spotlight on your body's internal sensors. They enable us to feel pain, give us a prod when we need a drink and let us know when we've eaten enough food (although this one is a little easier to ignore). These specialised cells definitely aren't voiced by Amy Poehler, but it's a fun way to think about how our body functions. It gets five glittery gold stars from me!

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
I'm in the mood for watching the *Vikings* TV series after this issue. It might not be historically accurate but it's still fun.

Siobhan Maguire
Production Editor
Siobhan is joining us full-time next issue, and already she's been on more team socials than Andy (who refused to see *Pitch Perfect 2*).

Phil
Staff Writer
Although my feature this month required a TITANic effort, I still had time to enjoy some tennis and an ice cream. Yum.

Jackie
Research Editor
Just like Edwin Starr, I often wonder "War... what is it good for?" Rapidly advancing tech, apparently. Hopefully it will keep our soldiers safe!

Jo
Assistant Designer
I've been busy with the Brain Dump section this issue and now I feel like I'm more than a match for any pub quiz or dinner party!

Jo
Features Editor
This issue has made me want to visit Yellowstone, the Plitvice Lakes and Christmas Island. I better start saving my pennies now then.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

Why is fluoride good for your teeth? **Page 40**

How do flying fish soar over the sea? **Page 64**

How do you fly a helicopter? **Page 54**

Which drill is best for making holes in walls? **Page 21**

How do we know the Milky Way is a spiral? **Page 76**

What is daily life like for a medieval monk? **Page 33**

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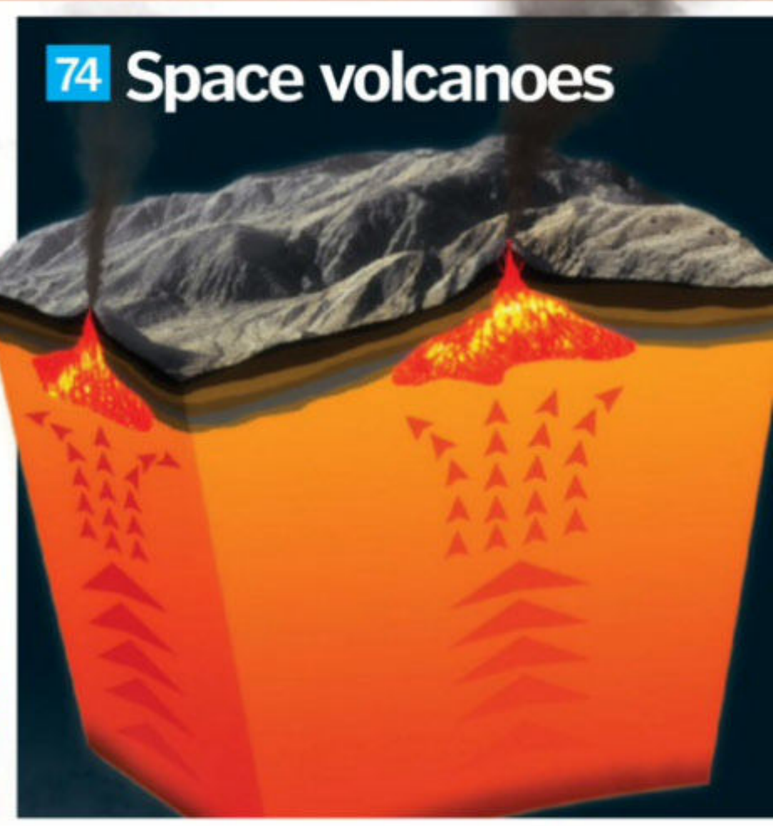

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Meet the experts...

Laura Mears
The 'other' senses
Despite what you've been told all your life, you have way more than five senses. Laura's on hand to reveal what they are and how our body uses them to balance, feel pain and more.

Alicea Francis
Vikings attack!
Editing **All About History** magazine, Alicea knows a thing or two about bloodthirsty civilisations and deadly weapons, so who better to write about the infamous Vikings?

James Hoare
Super soldiers
The Editor-In-Chief of **All About History** and **History Of War** looked to the future this month when he wrote about tomorrow's soldiers and the suits that will help them win the war.

Lee Sibley
Multi-million dollar motors
The Editor of **Total 911** breaks down the cost of a supercar, revealing why they can command more than the price of several houses!

Ceri Perkins
Yellowstone Park
Ceri fell in love with the natural wonders of America's first national park. Check out the live webcam online to watch Old Faithful blow in real-time!

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Your first look at the next issue of **How It Works**

A room with an underwater view

Sleep below sea level in Dubai's luxury villas

As well as offering you the chance to climb to the top of the tallest skyscraper in the world, Dubai will soon allow you to reach great depths too. A new luxury retreat called The Floating Seahorse features underwater bedrooms with breath-taking views of the surrounding marine life under the waves.

Described as a boat without propulsion, each of the 42 units floats on its own plot of sea in the Arabian Gulf, just a short boat ride from the Dubai coast. While two levels above water contain a kitchen, living area and Sun deck with glass-bottomed Jacuzzi, the bedroom is fully submerged, so you can sleep in your own aquarium.

Each floating home can be moved to find some extra privacy

The Floating Seahorse is expected to be completed by the end of 2016

Saving its seahorse namesake

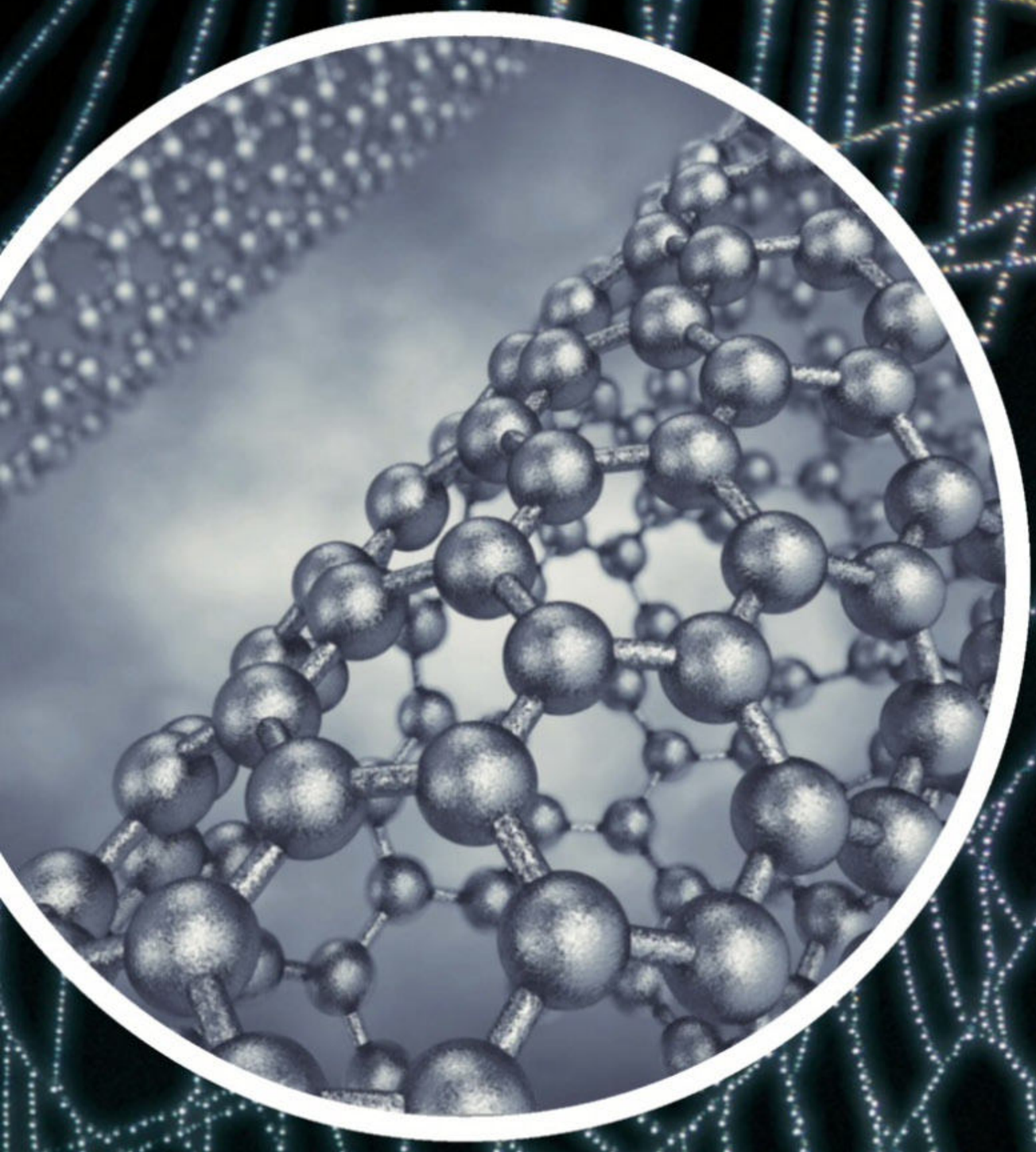
As well as providing stunning accommodation for those lucky enough to afford a stay, the Floating Seahorse also aims to help protect its endangered namesake. The Kleindienst Group – the company behind the project – will create an artificial coral reef beneath the luxury retreat to serve as a protected area for seahorses to live and breed.

Although the status of many seahorse species is unknown, some, such as the giant seahorse and the hedgehog seahorse, are classified as Endangered. One of the main causes for their decline is the trade of seahorses for Chinese medicine, as they are believed to have aphrodisiac and anti-aging properties.

They are also popular as souvenirs, as they can be dried and turned into jewellery, and as aquarium fish, but they rarely survive for long in captivity. However, those that are left in their natural habitat are still not safe, as the world's coral reefs are also under threat from climate change, marine pollution and over-fishing.

An estimated 20 million seahorses are traded each year for Chinese medicine

Scientists sprayed spiders with a mixture of water and graphene particles



Super-strength spider webs

Graphene-infused silk can catch a falling plane

It was only very recently that spider silk was overtaken by limpet teeth as the world's strongest biological material. However, scientists are now giving this amazing fibre another chance at the top spot, by spraying spiders with graphene. They are not sure how, but the creatures were able to incorporate the material – which consists of a single layer of carbon atoms and is 200 times stronger than steel – into their silk. This enabled them to create webs that were over three-times stronger than the toughest natural silk known to man, which is produced by the giant riverine orb spider.

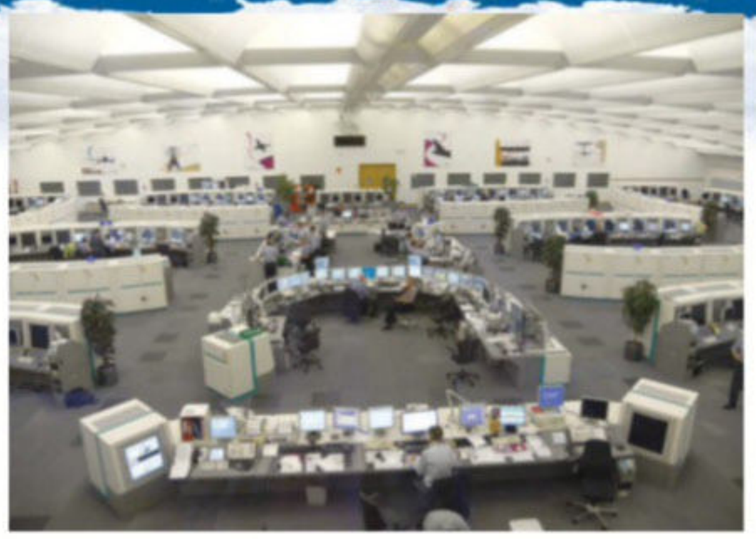
Air navigation providers are testing the possibility of using space-based operations

The future of air traffic control

Satellite tracks aircraft from space for the first time

A European Space Agency mini satellite designed to monitor the Earth's vegetation growth has stumbled upon another purpose. Proba-V has been able to track the positions of more than 15,000 aircraft from space for the first time. Although they were never designed to be picked up from so far away, the satellite is able to detect signals indicating each aircraft's speed, position and altitude.

This discovery could enable the minimum separation distance between aircraft flying in areas without radar coverage, such as over the Atlantic Ocean, to be reduced, safely increasing global air traffic capacity.



Air traffic control could soon be able to monitor aircraft far more effectively from space

Snow cleaning will be needed if the telescope's mirror is contaminated during testing

'Snow cleaning' the next space telescope

Engineers blast mirror with carbon dioxide snow

The James Webb Space Telescope is expected to be the most powerful device of its kind ever built and will replace the Hubble telescope in 2018. Its mirror will be seven-times larger than Hubble's, enabling it to take even more detailed images of deep space, but to do this it must be kept super clean. This is why engineers are currently practising 'snow cleaning' on a test mirror, blasting carbon dioxide snow at the surface to knock small dust particles off the mirror without scratching it.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Isolation killed the woolly mammoths

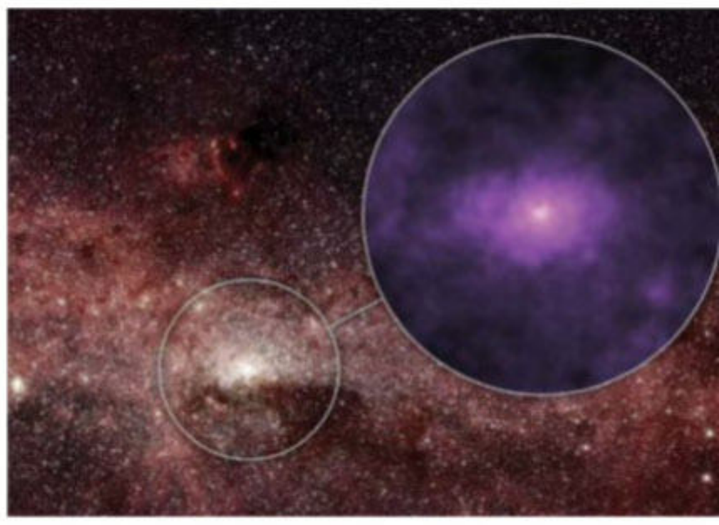
The last woolly mammoth is estimated to have died around 4,500 years ago. New analysis of their DNA has revealed that their population dwindled for around 5,000 years, as they became isolated on Wrangel Island in the Arctic. This forced them to become chronically inbred, which was shown by genetic analysis of the remains of two woolly mammoths.

A car can split in two

The Lane Splitter is not your ordinary car. At the touch of a button, the three-wheeled vehicle splits into two separate bikes, powered by their own electric motors. When the two parts separate, the front tyres split and expand, providing greater stability. Currently, the costs associated with producing the Lane Splitter mean it won't be available for mass production, but it is still a very cool concept.

There's a solution to jet lag

A group of scientists believe they may be able to cure jet lag. They have discovered our internal body clock's molecular reset button, which they hope will allow them to treat jet lag, and possibly even depression. They found that light triggers phosphorylation in the brain, which causes our body clocks to sync with the light cycle of a specific area.

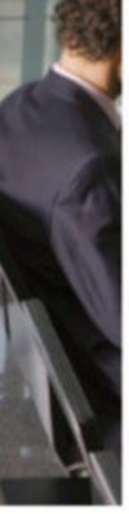


Zombie stars can scream

NASA's NuSTAR has observed an unusual glow of high-energy X-rays, which scientists believe could have been produced by zombie stars as they feed their stellar neighbours. The zombie-like "feeding" on other stars differs depending on the nature of the normal star, but can result in X-ray eruptions.

Diesel can be made from CO2 and water

Audi believe it has found a carbon-neutral method of powering vehicles. The car giant has been able to produce a crude oil, which can be refined into diesel, from only carbon dioxide and water. The entire process is green, as a renewable energy source is used from start to finish. The e-diesel enables cars to run quieter, as well as produce fewer pollutants, and is already being used to power a German minister's official car.

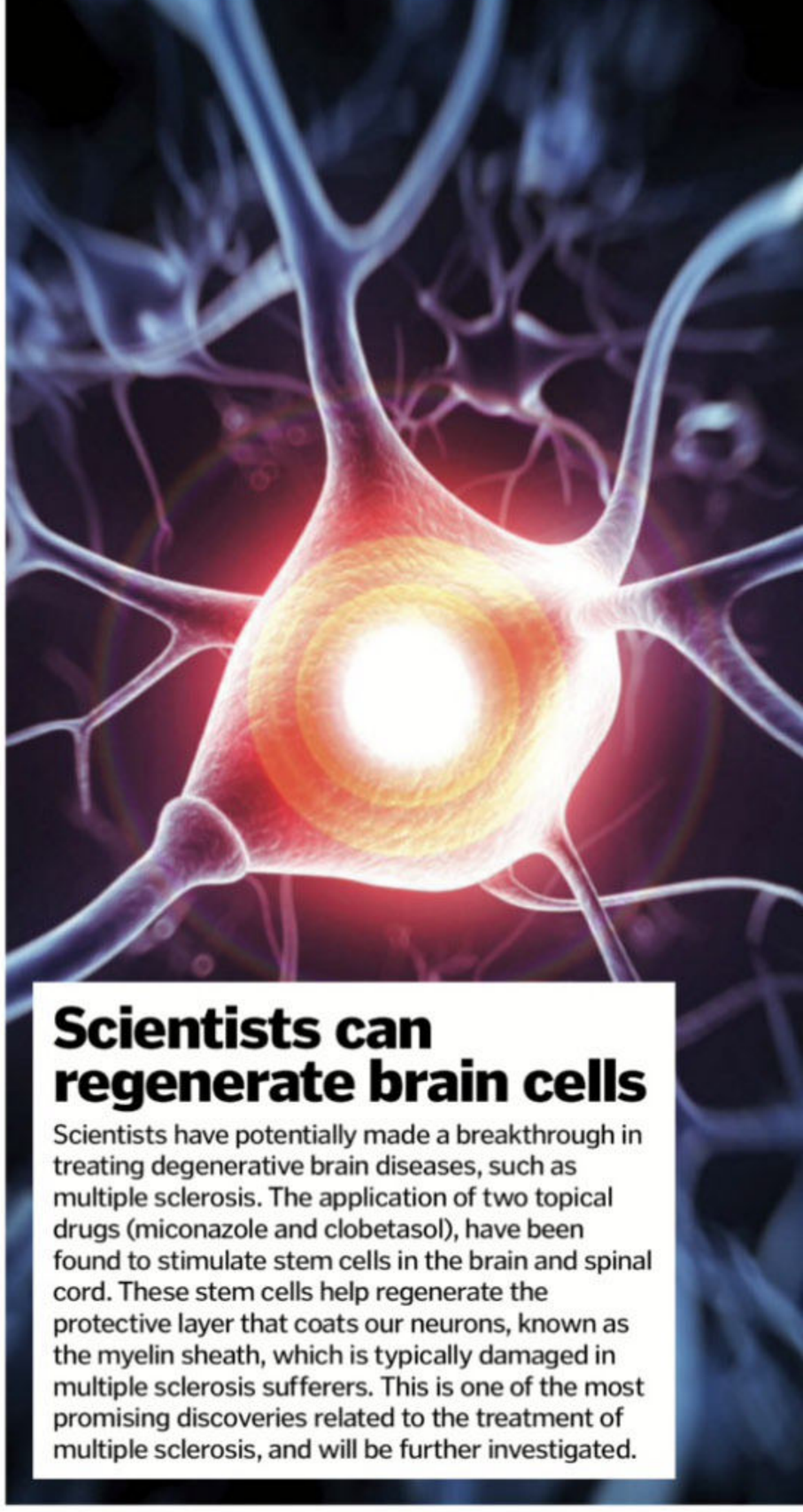


Police can distinguish between identical twins

Until now, DNA analysis has struggled to tell the difference between identical twins, as they have the same genetic code. However, as they age, experiences such as smoking or diet can create variations in their DNA. By melting their DNA, police now have a technique to differentiate between identical twins. The more hydrogen bonds present in the DNA, the higher the melting temperature. This enables them to identify differences based on genetic changes which occur as a person's body is influenced by their lifestyle and environment.

A magnetic light switch cover keeps keys safe

We've all lost our car or house keys at some point, leaving us frantically searching for them all over our homes. The NeoCover is simply a traditional light switches. with a magnetic strip inside. The strip is capable of supporting the weight of up to 27 keys on a single chain, or pens, lighters and even a claw hammer if needed.

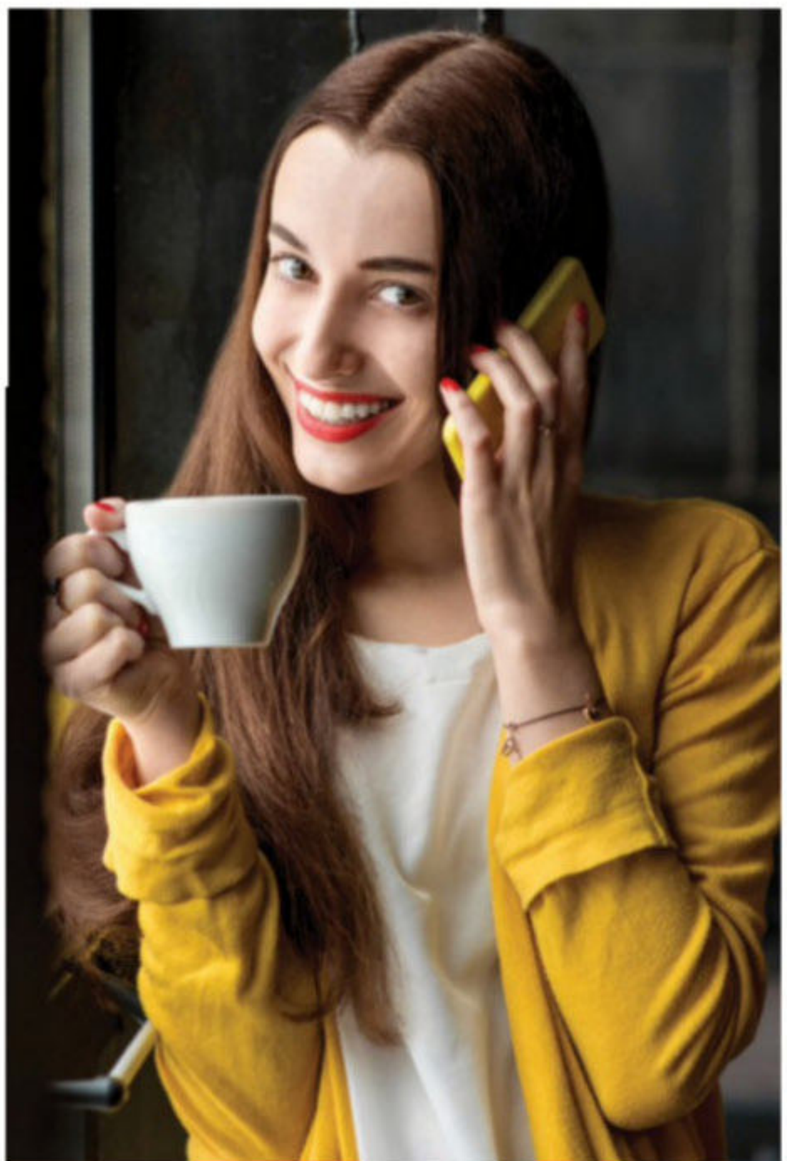


Scientists can regenerate brain cells

Scientists have potentially made a breakthrough in treating degenerative brain diseases, such as multiple sclerosis. The application of two topical drugs (miconazole and clobetasol), have been found to stimulate stem cells in the brain and spinal cord. These stem cells help regenerate the protective layer that coats our neurons, known as the myelin sheath, which is typically damaged in multiple sclerosis sufferers. This is one of the most promising discoveries related to the treatment of multiple sclerosis, and will be further investigated.

Your ear can unlock a smartphone

Specialist fingerprinting hardware is commonplace in many of today's smartphones, however it may soon become redundant. Researchers have created a new sensor that can recognise the unique shape of several body parts, including your ear and palm. Essentially, it uses your phone's touchscreen as a biometric scanner, which is much cheaper than installing fingerprint-recognition software.



Super matches burn in water

The inventors of the new UCO Stormproof Matches have created the most durable match ever seen. They feature an incredibly tough coating, which continues to smoulder even when the match is submerged in water or buried in dirt. Once the match is reunited with an oxygen source, the smouldering coating will immediately reignite into a burning flame. These matches are an excellent alternative to lighters, which often fail in tough conditions or high altitudes.

SUPER SOLDIERS

HOW TECH IS TRANSFORMING THE FUTURE OF WARFARE

Armies are getting smaller, but soldiers are growing more powerful than ever thanks to amazing new technology

War has been one of the greatest spurs to science in history. Developments as diverse and far-reaching as space travel, superglue, duct tape and microwaves owe their origins beneath camouflage netting and behind sandbags.

A century on from the start of World War I's disastrous Gallipoli Campaign and 70 years on from the end of the World War II and the dropping of the atomic bombs, the catastrophic loss of life looms far larger in the memory than the technologies these conflicts helped to inspire.

Today's military innovations, though, are focused not just on getting the job done and winning the fight, but doing so as quickly as possible and bringing the men and women in the boots home to their families in one piece.

"There's obviously a trend toward trying to increase personal protection as far as possible given that training is ever more extensive and armies are getting smaller and smaller," explains Justin Bronk, military sciences analyst at The Royal United Services Institute for Defence and Security Studies, a think-tank founded in the 19th century to advise the British government.

"I think the basic picture of a soldier probably won't change too much – [like] body armour which is scalable depending on the threat expected. Until you see full exoskeletons there'll still be a trade-off between how much a threat and therefore how protected you want to be versus how much you want to move, so you'll still have your pelvic body armour, helmet and various kinds of advanced night vision scopes."

Armour could be significantly strengthened by a number of means beyond the current protection that's offered to infantry. There are ongoing experiments in liquid armour, which would harden on impact but remain flexible enough to allow the soldier free movement, and nanotechnology, which enables materials to be manipulated on an atomic, molecular and supramolecular scale.

"If you are engineering something to a nanoscale you can then create vastly more resistant and strong materials because they don't have any imperfections," explains Bronk. "You can design a lattice structure instead of having to either kiln something or cast something. You can effectively build up, for example, carbon fibre-infused ceramics at a nanoscale if you were doing it like that. You can build it so it's a perfect lattice structure and you get fantastic integration between the materials so it's more stronger pound-for-pound than something that's made in the more traditional way."

Innovations like superstrong exoskeletons and bulletproof carbon-fibre body armour are one option, but Bronk believes that better intelligence – not just from commanders on the other end of the radio, but right there in the field – also has a big part to play.

"The main focus for standard infantry is going to be a mix of sensors," he says. "So for example we're already seeing trials of a combination of thermal and infrared vision aids for seeing at night. At the moment soldiers tend to use infrared, your standard green *Predator*-style night vision to see and move around, but when they're actually engaging targets at night, they use thermal. Obviously this involves more equipment and thermal scopes are traditionally rather large, but they give much better definition. One way of increasing efficiency is to use an integrated binocular/monocular attached to the helmet so that you don't have to carry two things, you can carry one power pack for both and switch between them quickly."

These sort of neat fixes in existing technology might not sound like much, but they can make a huge difference to both the weight a soldier carries and the convenience of not having to fumble around with a variety of equipment.

"There are things like the Fighting Load Carrier vest which uses a small amount of power to distribute the load from the shoulders toward the hips and make sure the load is even," offers Bronk as an example. "It also gives an exact GPS fix of the soldier to within an axis of about five to ten metres [16.5 to 32.9 feet] and it also integrates a radio, so you're there looking at addressing one major problem and then seeing 'What could I add in there that would also make the overall equipment package more efficient and lighter?'

"There's also going to be a huge focus on engaging communications and networks. We're basically still using satellite communications and radios. I think there'll be continuing heavy reliance on digital technology, but at the same time we'll be much more aware by that point of the dangers of relying on a guaranteed supply of information in a contested environment because I just don't think that's going to be possible. We'll have to fall back a lot more on command intent [decisions on the ground] as opposed to minute-by-minute instructions.

"Also, I think there'll be a lot more micro-drones and other machines. In the end though, soldiers will still be there. There'll still be people with guns and body armour."

Virtual reality training

Simulations may already have a place in air-force training, but now soldiers have a chance to put their skills to the test in virtual-reality combat zones.

Wearing head-mounted displays (HMD) or VR glasses such as Oculus Rift, soldiers can explore a variety of scenarios, such as the challenges of administering first aid to a wounded comrade while under enemy fire. This is all realised in a 360-degree 3D environment that changes the image with the movement of the head and the body, via an in-built tracking system.

Some battlefield simulation programs are even more realistic still. Polish troops train with integrated feedback that administers a small electric shock when the soldier gets 'shot', while the US Department of Defense is so committed to the idea that they want every soldier to have a virtual avatar that can be customised to reflect their individual skills and weaknesses.

US Army soldiers training with the Dismounted Soldier Training System (DSTS)

SOLDIERS OF TOMORROW

How the Future Soldier project plans to change the face of warfare

Exoskeletons are only the beginning when it comes to preparing for tomorrow's conflicts. The greater carrying power being developed by the likes of Lockheed Martin will let soldiers field a whole new package of weapons and armour that will turn a single soldier into a one-man war machine capable of dealing with any situation.

"There's obviously a trend toward trying to increase person protection as far as possible given that training is ever more extensive and armies are getting smaller and smaller," explains Bronk.

A continuation of the Future Soldier project launched by the US and its allies in the Nineties, this new generation of super soldier programmes such as the US Army's Future Soldier 2030 Initiative will bring together similar combinations of next-generation military technology. This ranges from heavy carbon-fibre body armour to more sophisticated sensors that monitor the soldier's health and software to instantaneously decipher speech and weigh up threats.

US Army Rangers conduct a training exercise in Land Warrior gear

Head-up display
The soldier's HUD provides facial recognition and threat assessment, and a 180-degree field of vision.

Recoilless rifle
Firing caseless rounds rather than bullets, the rifle will have lethal and nonlethal settings.

AI wingman
An AI 'buddy' constantly monitors the soldier's health and suggests solutions based on the data.

Electronic textiles
Textiles transmit the data and power around the suit without cables or wires.

Nano-ceramic armour
Existing ceramic plates are strong enough to stop a rifle bullet, those engineered by nanotechnology would be far stronger.

Wrist display
Wrist-mounted display will be able to show anything normally visible through the HUD.

Norwegian naval commandos practice antiterrorism operations in the NORMANS Future Soldier system

LAND WARRIOR

While we wait for armoured exoskeletons and integrated firearms, the US's Land Warrior (since superceded by the Nett Warrior) and similar systems such as the UK's FIST (Future Infantry Soldier Technology) and France's FELIN (Fantassin à Équipements et Liaisons Intégrés/Integrated Infantryman Equipment and Communications) – represent a package of cutting-edge military technology that we don't have to wait 15 years to see. In fact, it's in use right now.

Networked for battle
The antenna can receive video and data as well as voice communications.

Monocular sight
As well as showing what the rifle's camera sees, the monocular sight has both night vision and infrared.

Camera sight
A camera mounted on the rifle allows the soldier to shoot from cover without exposing their head.

Power supply
Lithium batteries power the whole system, including a Fighting Load Carrier vest which takes some of the weight from the soldier's back.

Smart gun
The rifle's crosshair is shown on the HUD and it can be fired by voice command or electronic trigger.

Environmental protection
As well as providing full NBC (Nuclear, Biological, Chemical) protection, the suit will be climate controlled for extremes of temperature.

Exoskeleton
A smart exoskeleton increases the soldier's strength and speed to reflect his or her movements.

Power
Chargeable lithium-ion batteries provide four to five hours of power. These can be replaced when they run down.

An Australian soldier trials a new grenade launcher attachment during the development of their Future Soldier system, Land 125.

DID YOU KNOW? *18 per cent of the average soldier's armour is capable of stopping a bullet; some suits now offer 60 per cent cover*

ARMY EXOSKELETONS

Soldiers carry more gear than ever before, could this supersmart exoskeleton take the strain?

Soldiers clunking across battlefields in powered exoskeletons may have long been a staple of many a science fiction writer's wildest wishlist, but they're starting to become reality.

Taken from the Greek word meaning 'outer skeleton', exoskeletons are inspired by the hardened shells of the insect world. They involve a frame of hydraulics which magnify the leg and arm movements of the wearer, enabling them to take more effortless strides while carrying even greater weights.

Military exoskeletons trialled as far back as the Sixties – such as General Electric's Hardiman – were able to increase the magnitude by a factor of 25, making lifting an 11-kilogram (24 pound) load as easy for the wearer as lifting 0.5 kilograms (one pound). They even had force feedback – similar to an Xbox or PlayStation controller – so that the operator could get an idea of the resistance that he or she was experiencing. These projects were ultimately unsuccessful as the early exoskeletons reacted unpredictably (and sometimes violently) to anything less than gentle movements. Sadly, for General Electric, gentle wars are few and far between.

While many current exoskeleton projects have medical uses in mind – enabling those who are unable to walk to do so without crutches – XOS and XOS 2 (developed for the US Army by Raytheon-Sarcos), Hercule (developed for the French Army by RB3D), and Human Universal Load Carrier, better known by its intimidating acronym of HULC, are primarily military endeavours. Developed by Ekso Bionics and Lockheed Martin, HULC is a lower extremity exoskeleton powered by a lithium-ion battery that works to redistribute the weight across the hips and legs – this will enable its operator to comfortably carry 91 kilograms (201 pounds) with far less effort.

The increasing weight of a soldier's gear – including standard weapons, ammunition, rations, water, first-aid kits, basic tools, satellite phone, GPS, helmet and body armour, and depending on the scenario, anything else from snowshoes and camping stoves to night vision goggles and micro-drones – is a growing worry for commanders. Indeed, the consequences of lugging around a weight of anywhere between 36 and 54 kilograms (79 and 119 pounds) can be severe – perhaps even deadly.

The incredible HULC

Inside the tech that will give tomorrow's soldiers super strength

Weapons mount
A swing mount is available which hangs over the chest to take the weight of a weapon away from the soldier.

Smart tech
A microprocessor linked to sensors detects the wearer's movements and then calculates movements in the exoskeleton to match them.

Massive weight
The average soldier could be carrying up to 54kg (119lb) of kit. HULC can enable them to comfortably carry up to 91kg (201lb).

Power
Chargeable lithium-ion batteries provide four to five hours of power. These can be replaced when they run down.

Motor
An electronic motor, discretely mounted at the rear, drives the exoskeleton's hydraulics.

Legs like pistons
Hydraulics in the joints provide the motion, enabling the soldier to walk, run, bend, crawl or jump without any loss of agility.

Titanium frame
HULC's titanium frame is lightweight enough to keep it from hindering movement, but strong enough to take the weight of a soldier's kit.

"Distributing and managing a soldier's load can give enormous benefits in terms of combat endurance and efficiency," explains Bronk. "People ended up toting around up to 40 kilos [88 pounds] of stuff which means if they've been on patrol for a couple of hours and they go prone (lie face down) when they start taking fire, often they just can't get back up again!"

Far more flexible than earlier exoskeletons, sensors mounted throughout HULC's titanium frame and linked to an onboard microcomputer spur electric motors into action, enabling the limbs to match the operator's movements instantly. Lockheed's ambition is that the system will allow troops to be able to easily carry otherwise back-breakingly heavy gear, as well as bulkier armour – since the HULC offers no physical protection – which would normally be impractical for a soldier on foot to carry.

According to Bronk, what is currently holding them back from a roll out across battlefields is simple: energy.

"The basic problem with exoskeletons is that you need about ten kilowatts of power to run a typical load-bearing, armour-protected suit," he explains. "And you need to be able to run it for ten hours or so to make it mission-capable. Otherwise, if the power runs out, an exoskeleton becomes a massive impediment to the soldier's ability rather than a bonus."

Lockheed is currently investigating electrochemical and solid oxide fuel cells to solve exactly this problem, and the plan is for a 'long-range HULC' with a 72-hour battery life capable of powering bursts of speed up to 16 kilometres (10 miles) per hour.

Until the power issue is cracked, the type of exoskeletons most likely to hit the battlefield may be more difficult to spot than Lockheed's piston-powered HULC.

DARPA – the US government's Defense Advanced Research Projects Agency – is currently testing Warrior Web, a wetsuit-like 'soft exosuit' designed to be worn under the soldier's uniform to provide leg and joint support on only 100 watts of power. Instead of a titanium frame covered with battery-sapping hydraulics, Warrior Web uses computer-controlled textiles and wires that offer conventional orthopaedic support, as well as powered robotic systems in the legs to reduce strain on muscles and tendons.

It may not be the sleek armoured exoskeleton of videogames and action movies, but these sophisticated exosuits will take some of the strain from a soldier's bulging backpack and protect their muscles and joints from the effects of hours of patrols across rugged terrain.

Ultimately, whatever keeps a soldier in good shape will keep them alive.

Exosuits like Warrior Web are designed not just to carry more weight, but to protect muscles and tendons

Exoskeletons such as the French Army's Hercule can be fitted with 'arms' to enhance carrying strength

The HULC exoskeleton enables soldiers to comfortably carry up to 91kg (201lb)

THE FUTURE BATTLEFIELD

From drones to data, technology will be a soldier's true ally

As professional armies grow smaller and technology grows more advanced, soldiers may have to rely on machines for backup.

"You'll start to see more things like a micro-drone called the Switchblade, which can be carried in a backpack," explains Bronk. "It comes in a sort of tube, you launch this and you use a set of first-person-view goggles to see what it sees. That can be launched from behind cover, you throw it up and it flies around, and once you've seen who's shooting at you, you can guide it towards them and it's got a roughly grenade-sized warhead in it. That sort of smart micro-drone technology should soon be hugely influential."

The potential disruption caused by hacking and jamming technology will also ensure that while a soldier's ability to scan, transmit and receive more detailed information on what's round the next corner will increase, so will information on a potential foe's means to block it.

"In the land environment you'll start seeing greater capability for soldiers to connect with a network, to link up with, for example, helicopters that are coming to give them support, or fast jets or vehicles in order to increase the situational awareness and therefore effectiveness," confirms Bronk.

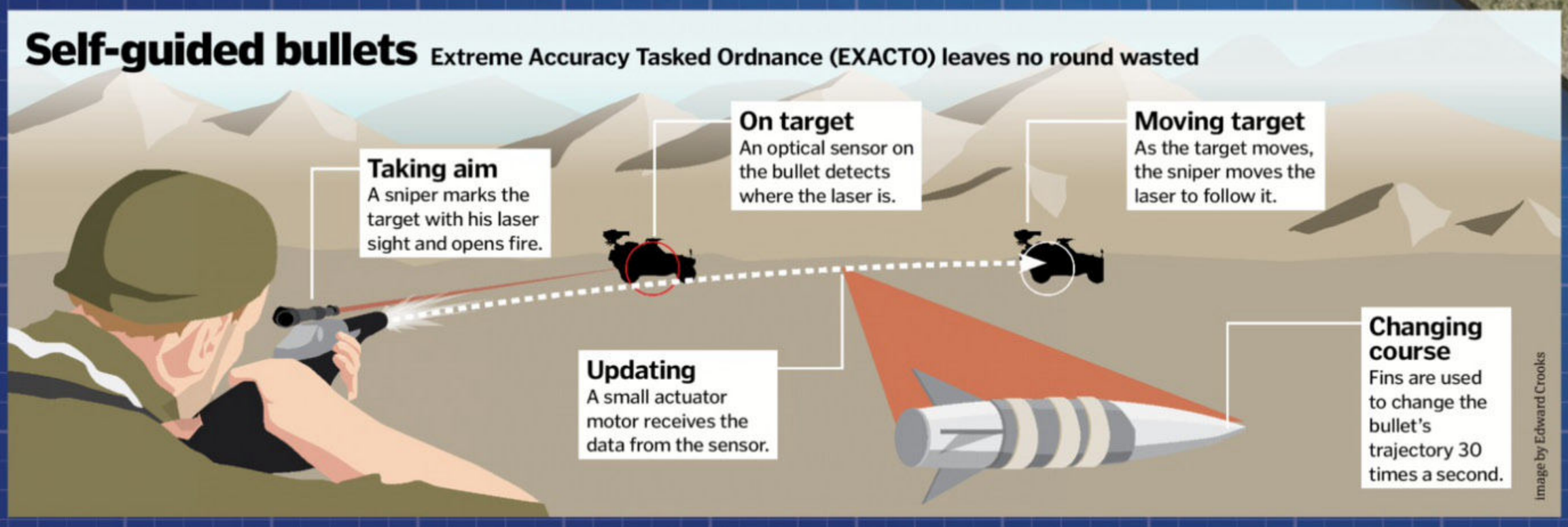
"That's got to be played off against the fact that you can't rely on electronics, particularly networked electronics against a serious opponent who really knows what they're doing because the first thing they'll do is jam it."

Robot reinforcements
Fully automated robots are already being developed to rescue the wounded and carry equipment over tough ground.

Combat drones
Controlled by soldiers in the field, hand-held microdrones can buzz ahead of troops to look for danger.

Researchers from MIT have built the Cheetah robot, which can jump over obstacles autonomously

Self-guided bullets Extreme Accuracy Tasked Ordnance (EXACTO) leaves no round wasted



DID YOU KNOW? *Overloading soldiers with more and more new kit is sometimes referred to as 'the Christmas tree effect'*

The Guardium is an unmanned ground vehicle (UGV) used by the Israel Defense Forces

Unmanned ground vehicles
Tracked or wheeled UGVs can patrol camps or scout ahead, while more heavily armed designs can join the fight.

A US marine launches a Raven surveillance drone to gather real-time intelligence

Medics on the move

Warfare has always led to huge advances in medicine, but despite progress, one of the biggest killers in the field is one of the most preventable – blood loss.

Fabrics like PolySTAT will be used in dressings to help the fibrin strands in the body cement a blood clot and stop bleeding, while more dramatic results will be provided by the XStat Rapid Hemostasis System – a syringe which fills the wound with a hardening polyurethane foam – or nanoparticles, which can be also be injected to speed up clotting in cases of internal bleeding.

Special forces scope

Rather than physically switching between green-tinged night vision and heavy heat-sensing thermal scopes in the dark, both of which require their own power sources, BAE Systems' ENVG III/FWS-I is just one of a new breed of scope which incorporates both in a single set of goggles

A wireless video link to the gun's sight also enables the ENVG III/FWS-I to aim without the need for a laser sight, which would easily give the game away in covert operations.

Head-up display

Increasingly sophisticated HUDs such as Urban Leader Tactical Response, Awareness and Visualization (ULTRA-Vis) will give soldiers all the information they need in one place, more accurately and intuitively than ever before.

The holographic augmented reality display will appear in the eyepiece mounted on a soldier's helmet and will show waypoints, information about the terrain and targets, and enable soldiers to add their own 'notes' to the landscape to share with their teammates.

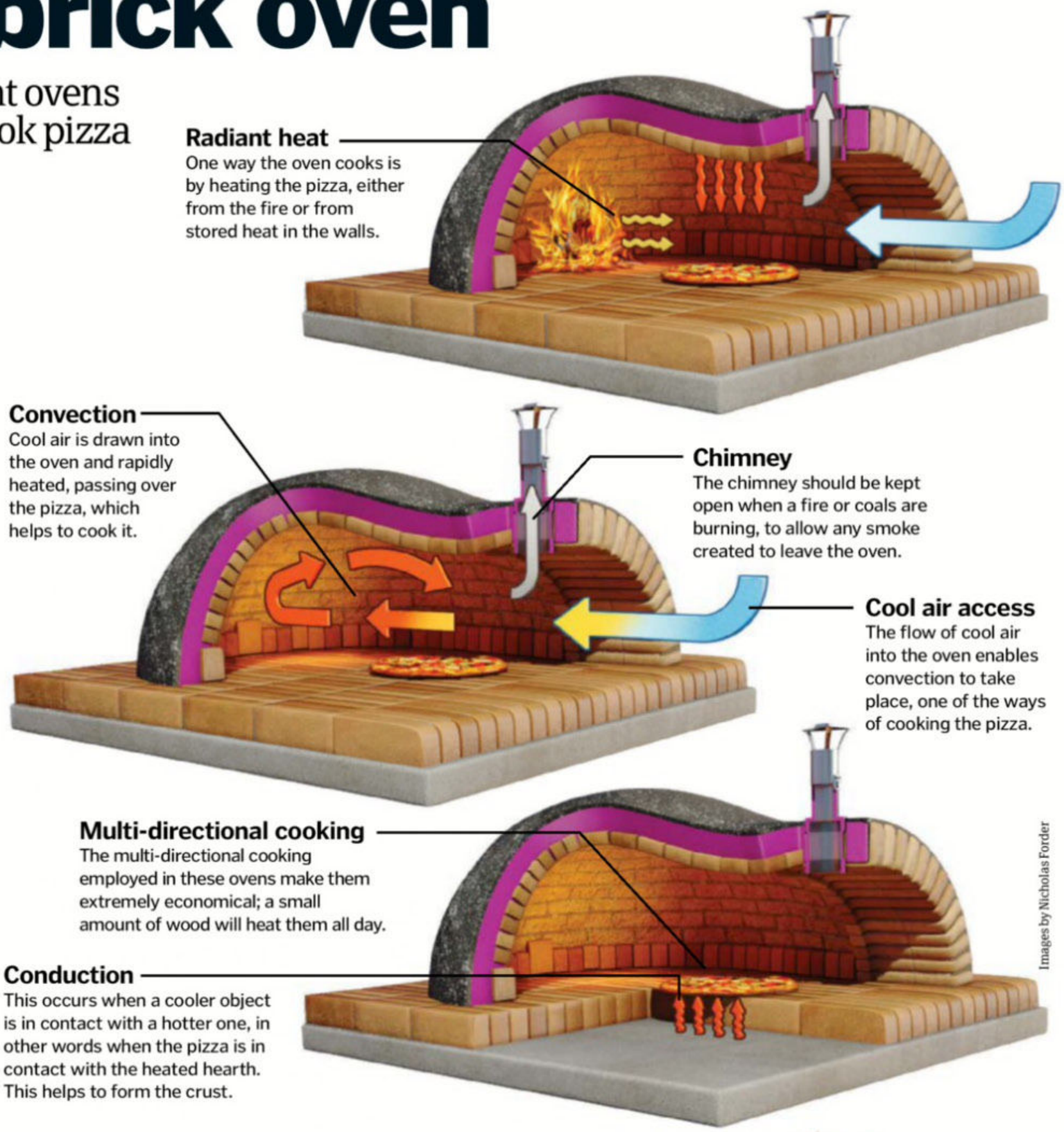
Fixed markers pinpoint targets or waypoints and remain in place, even if the user looks away

Inside a brick oven

Find out why these ancient ovens are still the best way to cook pizza

It's impossible to replicate the unique, savoury taste that wood-burning brick ovens give to pizzas. It is thought that this form of cooking has been around for at least 3,000 years, and was once the only means of baking bread. Examples of this type of oven have even been excavated in ancient Pompeii. In Italy, families tended to have their own brick ovens, which is the foundation of the country's modern pizza industry.

To cook a pizza, the first thing you need is a fire within the oven. While this burns, it's important to keep the door and chimney flue open. The oven's interior absorbs and retains the heat created by the fire, and should be left to do this until the oven chamber is white hot. The fire can then be left to die down, and the door and chimney can be closed so the oven reaches an even temperature. The oven is now ready to cook pizza, which typically takes less than two and a half minutes – much quicker than gas or electric powered ovens. Because they are able to retain heat for a long time, brick ovens can be one of the most efficient and economical methods of cooking.



How a smartphone knows up from down

The secret lies in a tiny device called an accelerometer

Have you ever wondered how your phone's compass knows which way you're headed? It's all down to the accelerometer, which is built into the circuitry of all modern-day smartphones. It can detect changes in orientation and tell the phone to respond accordingly by rotating its screen.

Accelerometers are made up of two fundamental parts. The first is the housing, which attaches to the object in question. The second is some form of mass, which is capable of moving when the object's orientation changes. This movement is the key to how it works, and is what the device measures in order to identify a change in the phone's orientation.

The accelerometer fitted inside a smartphone is an incredible piece of engineering. It is only 500 microns across, and is made by etching into a piece of silicon using potassium hydroxide. This clever device can be used for more than just identifying the orientation. It can be employed in gaming, particularly in driving games, where the user steers a vehicle by tilting their smartphone. They can also be used like a pedometer to track your daily steps, or even to detect tremors as part of an earthquake early warning system.


Apple has included an accelerometer in each generation of iPhone, iPad and iPod Touch

DID YOU KNOW? *Guitarist Eddie Van Halen used a power drill with his guitar in the Van Halen song "Poundcake"*

Your guide to household drills

Learn why selecting the correct drill bit lets you make the right hole in the right place

Rudimentary drills were invented by early humans so they could bore holes in materials. These days, the ability to drill provides society with a range of benefits, from accessing petroleum to curing toothache. The technology behind household drills is very simple in design. Squeezing the trigger initiates an electric motor, causing the chuck to spin the drill bit, which cuts into the target material.

Despite the simple design, inefficient drilling can still create problems, potentially damaging the material or the user in the process.

This highlights the importance of using the correct drill bit, which is where the real technological advancements lie. Today, there is a plethora of drill bits on the market in a variety of shapes and sizes. Most have either a tapered or sharpened end that cuts away material and an auger (a spiral screw thread), that removes the drilled material from the hole. Numerous speciality drill bits also exist. These have a unique design and specialised function, such as the cone drill bit, which can drill different-diameter holes in thin materials.

Certain geometric characteristics play a role in how drill bits cut through a material. The spiral, or rate of twist, is responsible for moving the drilled material from the hole and is varied depending on the required cutting speed. The material to be drilled determines the point angle, which is the angle formed at the bit's tip. Harder materials need a larger angle in order to drill them, while softer materials need a sharper angle. It's vital the correct one is used; this will reduce the risk of the drilled hole being uneven or in the wrong location.

HSS-Rolled
The most common kind of drill bit, ideal for use on plastic, wood and metal.

Spur auger
Similar in function to spade drill bits, they leave neater holes and require less torque to spin, hence they are a popular choice for hand-powered drills.

Brad-Point
This drill bit offers precise drilling in all types of wood, due to its centring tip.

Flat/Spade
With this drill bit it's possible to drill cleanly and accurately through wood. They are also easy to sharpen and inexpensive to buy.

Masonry
As its name suggests, this bit is used on concrete and bricks. They have a tungsten carbide coating for maximum durability.

HSS-Titanium
This bit will quickly drill a variety of metals, including silver, bronze, iron and copper.

Multipurpose
This drill bit works well for most tasks encountered domestically. It has a centring tip for added precision, along with tough, diamond-ground edges.

Glass and tile
Designed to work with soft tiles, ceramic porcelain and standard glass, this drill bit has a tungsten carbide head for superb durability.

How water is treated

The cleaning process that makes water safe to drink explained

The water that comes flowing out of your tap starts off as rain falling from the sky. It's collected in rivers and lakes as surface water, or beneath the Earth's surface as groundwater, but it would be unsafe to drink without treatment. This water contains dirt, pollutants and microorganisms that cause nasty diseases such as typhoid, cholera and dysentery. To remove these harmful impurities, drinking water is filtered and disinfected at a water treatment plant before it reaches your home.

The treatment process is often tailored to each water source, as some require more cleaning than others. For example, as groundwater is partially filtered when it trickles through soil and rock in the earth, it typically requires less treatment after it is pumped out of the ground. However, surface water must go through a few more stages of cleaning to remove large debris as well as smaller impurities. Some treatment plants also add extra ingredients to water, such as fluoride to help prevent tooth decay, or lime to soften it by removing calcium compounds.

Every time you have a glass of clean drinking water, you have the engineers that develop these water treatment facilities to thank for making it safe. They are continuously testing new methods for treating water that are cheaper and more energy efficient. One such method is solar disinfection, which involves using UV radiation from the Sun to damage and kill harmful bacteria in the water.

Engineers test and tweak the treatment process to make sure your water is safe to drink

Sedimentation takes place in large round tanks called clarifiers

From lake to tap

Filtering out dirt and debris from freshwater

DID YOU KNOW? *97% of the world's water is salty and undrinkable, 2% is frozen as ice, leaving 1% for human needs*

Hard & soft water

Rainwater is naturally weakly acidic and considered 'soft'. However, as it flows over and through the land, mineral compounds from rocks dissolve into the water. The most common are calcium and magnesium ions from chalk and limestone, and it's these that make the water more alkaline and 'hard'. Although hard water often tastes better than soft water and the minerals it contains are good for our bones and teeth, it also has several drawbacks. For example, when soap is added to hard water, more soap is needed to form a decent lather, and when the mineral ions react with the soap they leave behind an unsightly scum on your bath or shower. Plus, when hard water it heated, it produces limescale, which can coat the heating elements of kettles and washing machines to reduce their efficiency. The hardness of your water will depend on the geology of your local area and whether or not the treatment plant has softened it before delivering it to your home.

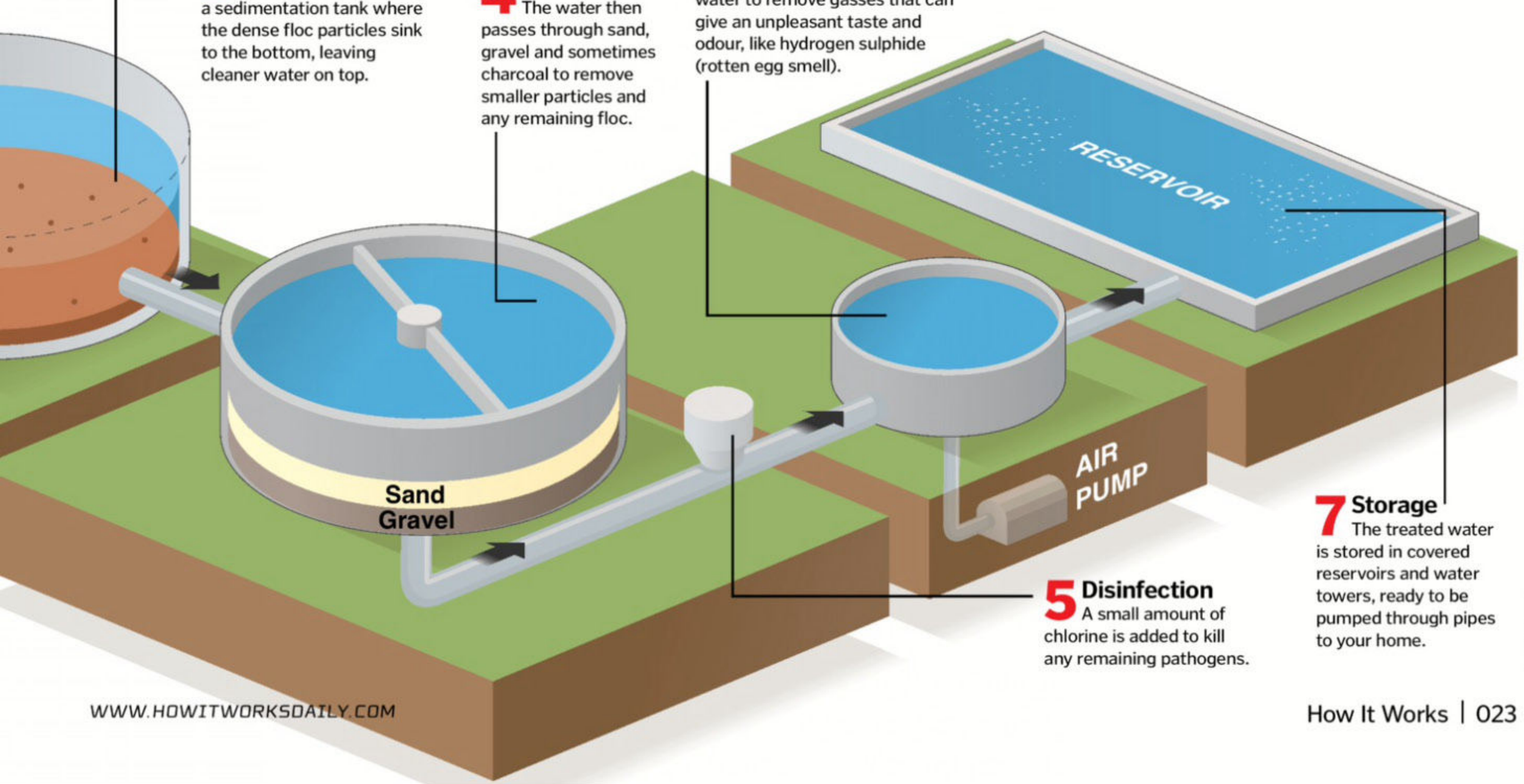
Some household appliances use ion exchange resins to soften water and prevent limescale

"Every time you have a glass of clean drinking water, you have the engineers to thank for making it safe"

3 Removing solids
The water flows through a sedimentation tank where the dense floc particles sink to the bottom, leaving cleaner water on top.

4 Filtration
The water then passes through sand, gravel and sometimes charcoal to remove smaller particles and any remaining floc.

6 Aeration
Air is forced through the water to remove gasses that can give an unpleasant taste and odour, like hydrogen sulphide (rotten egg smell).



5 Disinfection
A small amount of chlorine is added to kill any remaining pathogens.

7 Storage
The treated water is stored in covered reservoirs and water towers, ready to be pumped through pipes to your home.

Image by Acute Graphics

Faster 3D printing

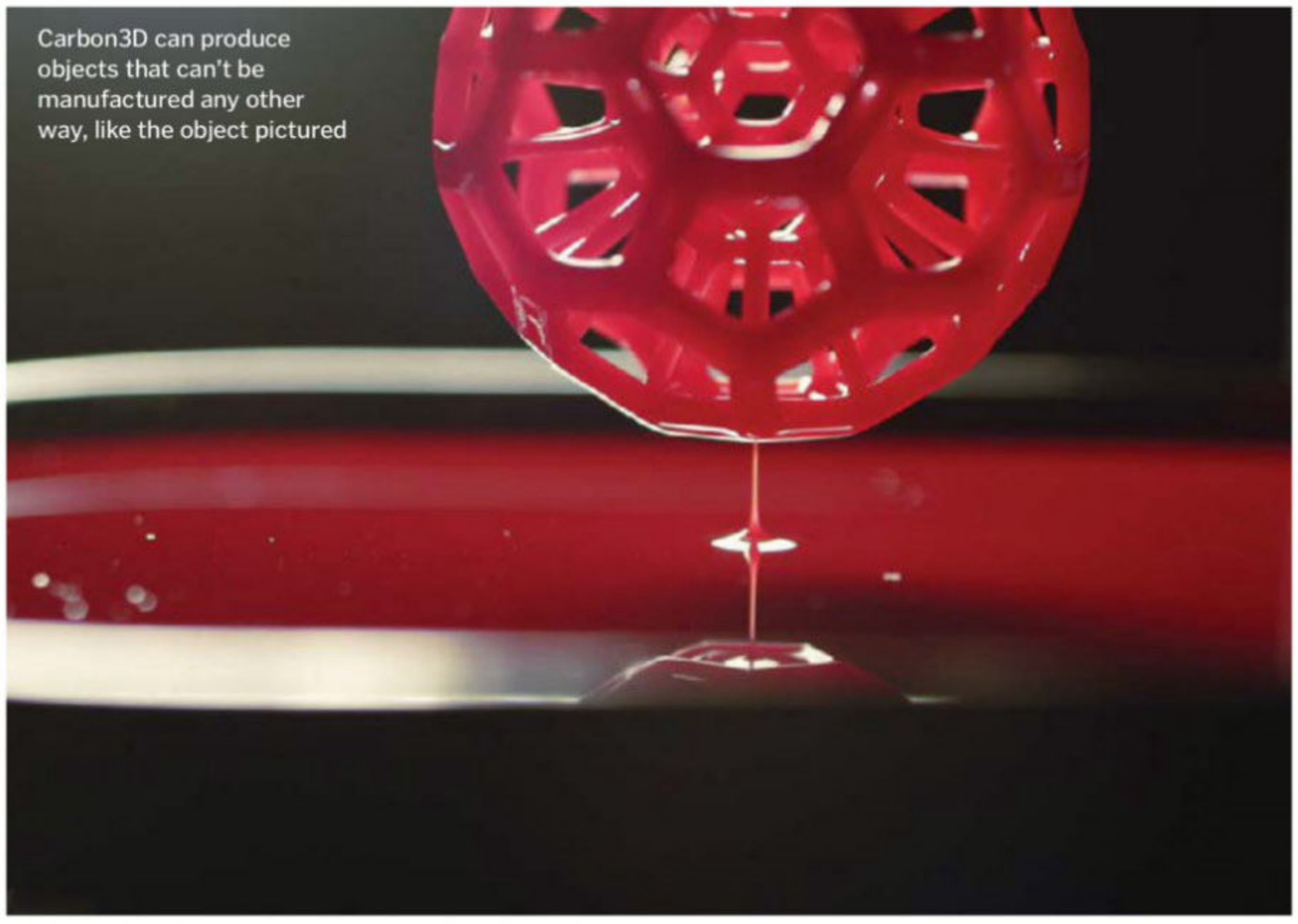
Inspired by *Terminator 2: Judgement Day*, the creators of Carbon3D aim to revolutionise 3D printing

The inventors of Carbon3D argue that traditional 3D printing is a misnomer. This process is actually just repeated 2D printing, which creates a 3D object as the layers build up. Traditional 3D printing also has a number of limitations. It is a lengthy process, often taking hours to produce a single object. The materials you can use are extremely limited, and the objects produced are often mechanically weak. These problems are the reason 3D printing is yet to be widely employed in mass production.

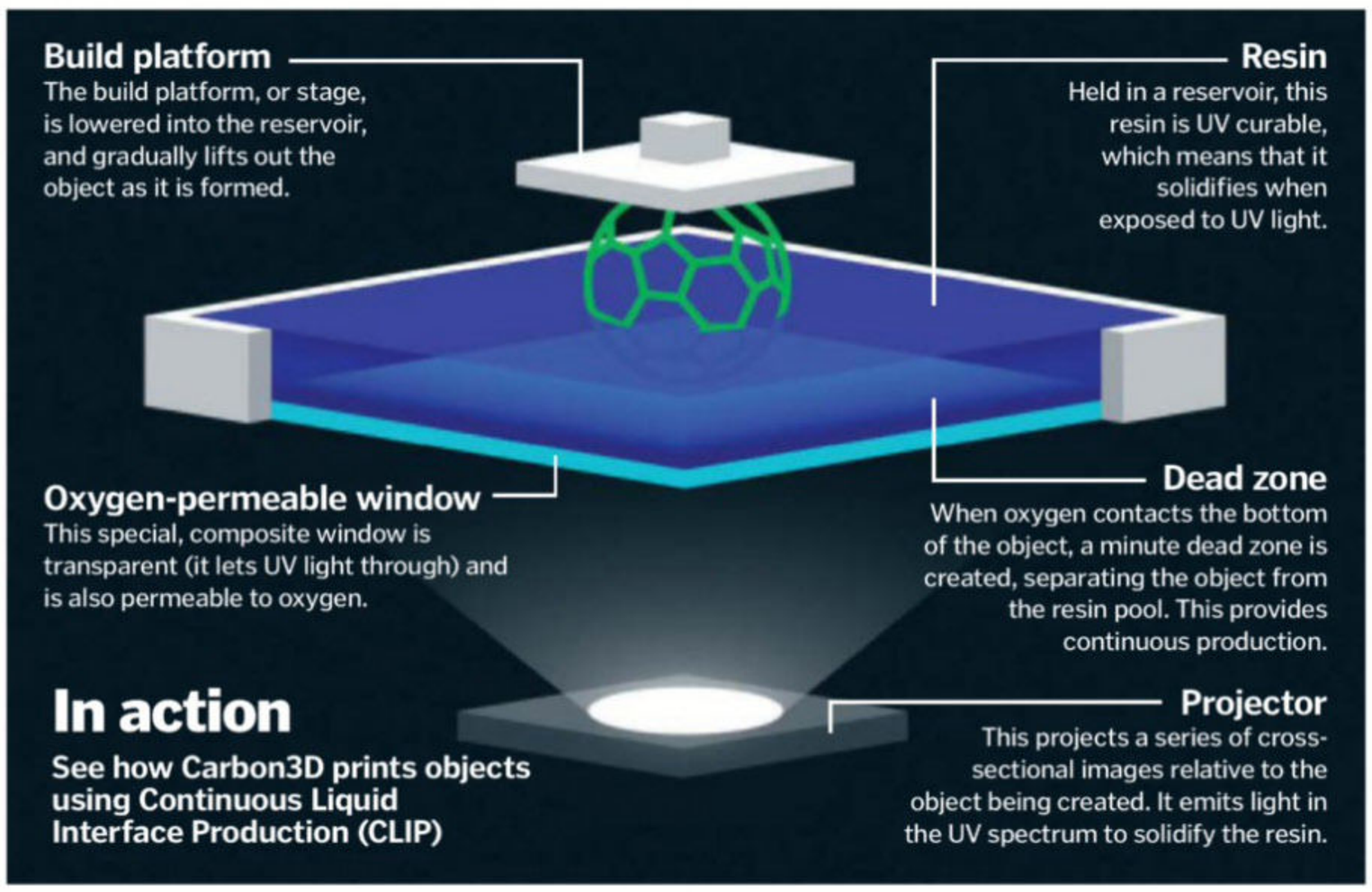
Carbon3D's creators believe their technology will change 3D printing forever. It's capable of producing objects between 25 and 100 times faster than traditional techniques, working in minutes rather than hours. Carbon3D utilises the properties of light and oxygen to 'grow' parts from a liquid resin. Light and oxygen, in this case, work as polar opposites. Light converts the liquid resin into a solid, whereas oxygen stops the resin from solidifying.

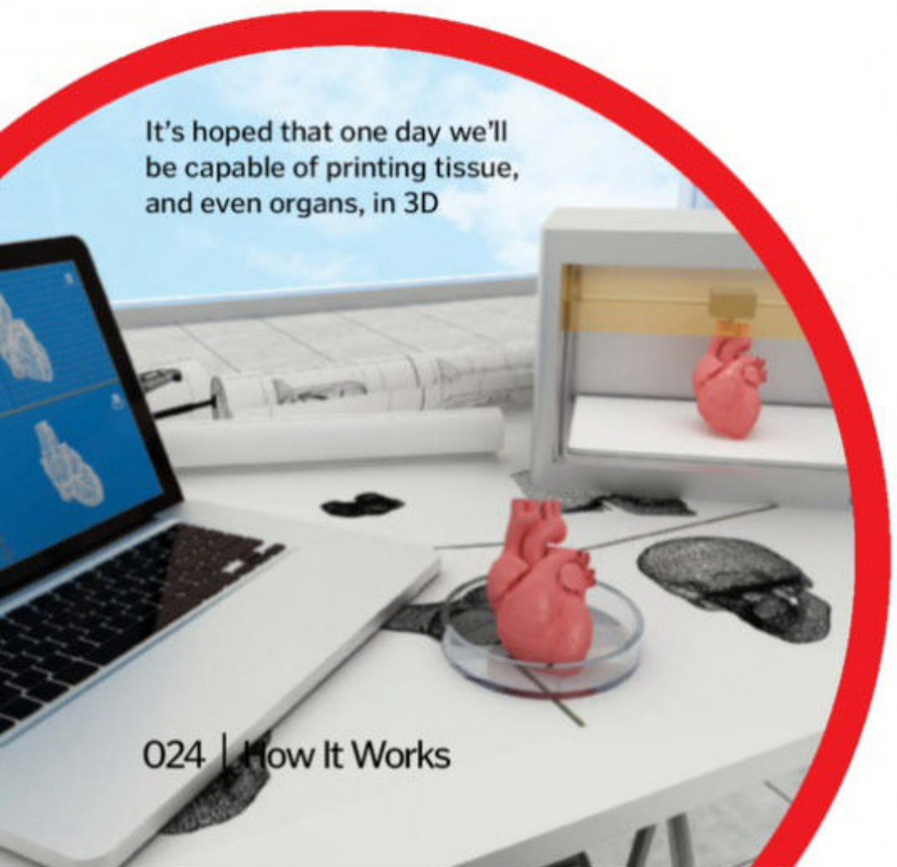
By harnessing these properties, the mechanical steps and layers seen in traditional 3D printing are eliminated, producing a smooth, structurally sound object. The real innovation lies in the 'window', which enables the oxygen flux to be controlled, creating a layer between the window and the object called a 'dead zone'. This area enables the object to be continuously grown from the resin.

With continued research and refinement, the creators of Carbon3D hope to see their technique used to mass-produce objects. They also believe that they will be able to offer personalised medicine by producing parts designed to work for individuals, such as small tubes used for widening arteries known as stents.



Carbon3D can produce objects that can't be manufactured any other way, like the object pictured





It's hoped that one day we'll be capable of printing tissue, and even organs, in 3D

AMAZING VIDEO!

Watch this amazing video to see how Carbon3D printing works

www.howitworksdaily.com

D5500

"You don't need many ideas, only a new perspective."

Andrius Aleksandravičius

I AM DIFFERENT

Shot by Andrius Aleksandravičius in Valencia
with 14-24mm NIKKOR | Exposure 1/100s | ISO 500
Photo © Andrius Aleksandravičius

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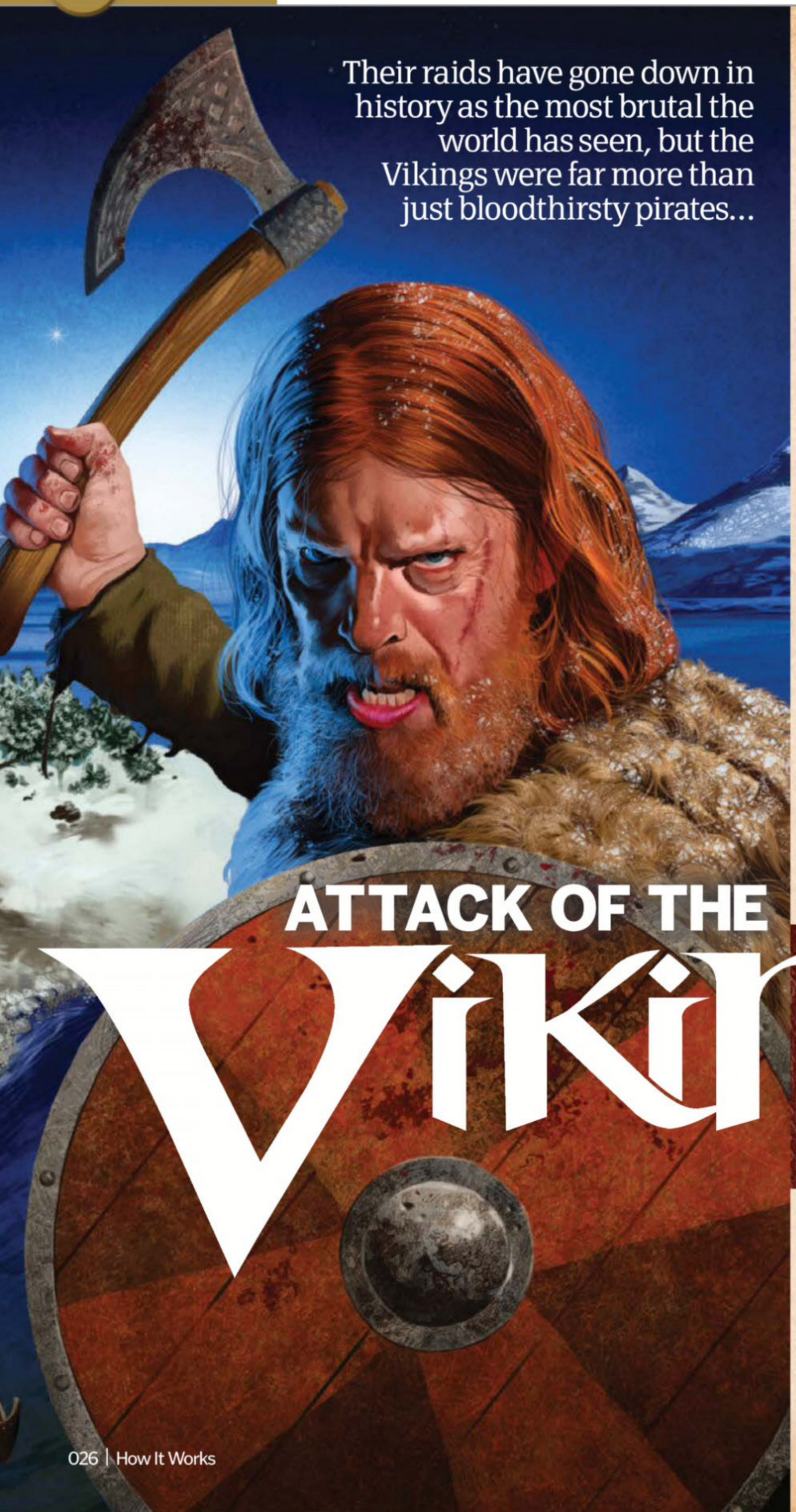


Their raids have gone down in history as the most brutal the world has seen, but the Vikings were far more than just bloodthirsty pirates...

ATTACK OF THE Vikings

Planet Earth has been home to some pretty terrifying civilisations over the years, but few would deny that the most fearsome of all were the Vikings. Best known for their mighty dragonships and bloodthirsty raids, these warriors from the north spent their days scouring the oceans in search of their next unfortunate target.

Unlike the Romans 1,000 years before, whose ambitions had been to conquer, the early Vikings set sail in search of treasure and slaves. Between the 8th and 11th centuries, they pillaged and plundered towns across Europe, ruthlessly killing anyone who stood in their way with a single blow of an axe, and capturing any bystanders to be sold on to wealthy citizens back home.

But what is considered most monstrous of all is the fact that their favourite targets were humble, undefended monasteries. These were packed full of gold and silver used in worship, along with valuable gifts from generous members of the parish, and were often located on remote islands – difficult for the townspeople to reach, but very easy for a seafaring warrior to get to. With only a few unarmed monks between them and the loot, it's easy to see why the Vikings took such a liking to these unbecoming treasure troves.

But the Norsemen were not mindless killers – far from it. Though it's undeniable that some did revel in the excitement of a raid, the majority left their hometowns with a more humane motive: to feed their families. Scandinavia's bitter climate meant that the land was generally unsuitable for farming, and the overpopulated towns were struggling to produce enough food for the inhabitants. The Vikings were desperate to seek out new farmland on more fertile shores, so set about developing ships that were strong enough to withstand a long journey across the stormy North Sea.

VIKINGS

Their expert ship-building skills, imaginative navigation techniques and entrepreneurial spirit meant that they were able to explore further than any civilisation before them, setting up countless trading posts along the way, while the wealth accumulated from hit-and-run raids allowed them to continue running their farms back home. Over the years, they began to colonise their new-found territories, and Viking settlers could soon be found throughout Europe.

Viking warriors

Despite their ruthless killing sprees, the early Viking raiders were primitive warriors. Their attacks were uncoordinated, and they lacked the numbers of their opponent armies. However, what these raiders had mastered was the element of surprise. By travelling in small fleets, Viking longboats could arrive on enemy shores completely undetected, leaving very little time for the townspeople to prepare for battle. It also meant that they could leave as swiftly as they had come.

As time went on, the raids grew in size, intensity and speed. By 851, the fleets had grown from three ships to over 300, and they formed a 'Great Army' of thousands. Unlike the early raiding parties who settled for merely hit-and-run attacks, this army had a very different purpose: to conquer.

Helmet
Spoiler alert! Viking helmets didn't have horns. Instead, they would have been a simple bowl shape with a spectacle guard.

Padded leather

Tunic

Mail

Armour
Professional warriors would have worn a chainmail shirt over their clothing, while less wealthy soldiers would have worn leather armour.

Shield
Viking shields were round and made out of wood, with an iron boss in the centre that was great for deflecting hard blows.

Tunic
Both men and women wore woollen tunics. Wealthier Vikings would also wear a linen undertunic beneath.

Leg wrappings
Strips of cloth were wrapped around the legs in order to gather the excess fabric of their baggy trousers.

Shoes
These were made out of soft leather. Vikings often stuffed them with dried grass and moss in order to keep warm.

Axe
Larger axes like this would have been used two-handed, while axes with smaller heads could be thrown.

Cloak
These would have been made out of thick wool and provided protection from the cold, wind and rain.

Clothing materials

Wool
Though Vikings are best known for being fierce warriors, many were also able farmers. Wool from sheep was spun into yarn and then woven into cloth to make tunics, cloaks and mittens.

Linen
Vikings made linen from flax – a type of plant. After harvesting the crops, famers would soak the stems in water and beat them. The stems could then be pulled apart into stringy fibres.

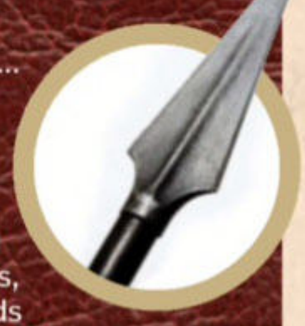
Animal skins
During the winter, animals were slaughtered and the skin from cows and goats was hung and stretched out to dry in order to make leather. Reindeers, wolves and bears were also hunted for their fur.

Vikings' deadliest weapons

Axe
Contrary to being big and cumbersome, Viking axes were actually lightweight and easy to handle. They could be swung or thrown with head-splitting force, and the injuries they inflicted were usually fatal.

Bow and arrow
These cleverly designed weapons had a range of over 200 metres (656 feet). Arrows would have been fired at the enemy at the very beginning of a battle, warriors could then close in to fight at a closer range.

Sword
Viking swords were difficult to make, and therefore rare and expensive. Only true warriors would own one. The rarest and most powerful was one called the Ulfberht, which was made of very high-quality steel for its day.



Spear
These were the most common weapons among the peasant class, as the spearheads were made of iron and therefore cheap to make. They were usually two to three metres (6.6 to 9.8 feet) long and could be used for throwing or thrusting.

Knife
These were the only weapons that could be owned by everyone, even slaves. The seax was slightly heavier than a normal knife but much easier to hide than a sword, so was useful for making quick, unexpected slashes.

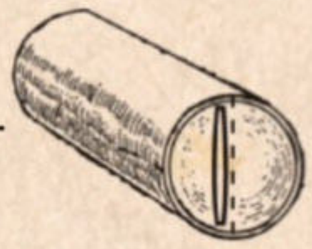
Viking voyages

The Vikings ruled the waves, and all thanks to one spectacular piece of craftsmanship: the longboat. Norse shipbuilders had mastered their art to such an extent that their boats were stronger, faster and more navigable than any civilisation before them. Their voyages took them as far east as Baghdad and as far west as North America, centuries before Christopher Columbus had even set sail, making them the first Europeans to discover the New World. They plotted the complex network of Russia's rivers and estuaries, often dragging their ships for great distances over land, and even took to travelling by camel when water was scarce. Though raids were a quick and easy way to accumulate wealth, they were hardly a long-term solution.

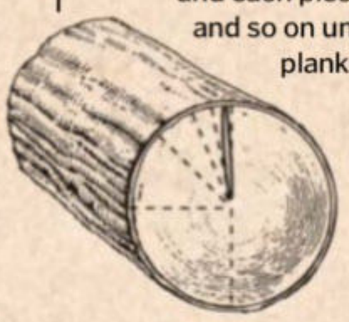
As time went on, the Vikings established several trade posts across Europe and the Middle East, trading Scandinavian goods like walrus ivory, soapstone and animal skins in return for slaves, silk and spices. Soon the Vikings were dominating the markets. With their growing wealth and power, the Vikings were able to take on bigger challenges in the form of sieges and invasions, and swiftly set about conquering cities across Europe. The Viking empire was born.

Building materials

Ships were made of wood which was fashioned into planks with axes and carving knives, rather than saws.



The oars of the ship were made of pine. The trunk would be split in two and the curved part was made smooth in order to glide through the water.



Oak was used throughout the ship. The trunk was divided in two pieces and each piece was cut in two and so on until around 20-30 planks were obtained.

Figurehead
The bow was decorated with a frightening figurehead, often shaped like a dragon or snake. This would scare any enemies who spotted the ship, and was also believed to ward off evil spirits.

Oars
Viking longships were fitted with oars that ran nearly the entire length of the boat. They used these when there wasn't enough wind to sail.

Keel
The keel was made with a single piece of oak measuring over 25m (82ft) long. This was very strong and meant the ship could survive even the worst storm.

DID YOU KNOW? *Vikings had excellent hygiene, bathing at least once a week – more than other Europeans of the time!*

Sail
Longships had a single sail that measured about 10 x 10m (33 x 33ft) and was made out of wool or linen. As there was no shelter on board, in very bad weather the sail could provide some cover.

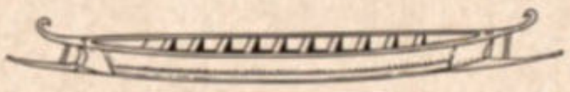
Hull
Ship hulls were made by overlapping planks of wood and securing them with iron rivets. They filled the gaps between planks with tar-covered wool to prevent leaks.

Cargo
War ships could only carry very small amounts of cargo. This included a supply of fresh water and dried meat.

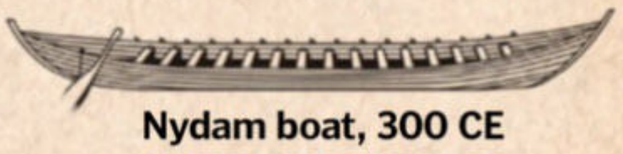
Rudder
This was located at the stern on the starboard side, and helped to ensure a straight course.

Ancestors of the Viking ships

The fishing activities along the Scandinavian coast encouraged the construction of ships. Archaeological discoveries and drawings have uncovered their incredible evolution.

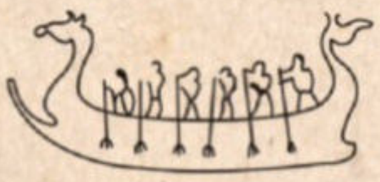


Hjortspring boat, 350 BCE

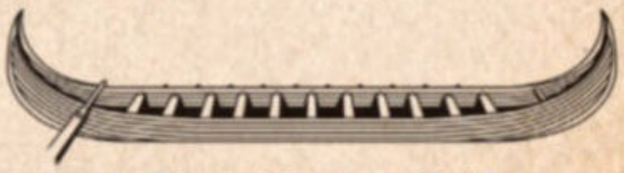


Nydam boat, 300 CE

Neolithic boat, 3500 BCE



Halsnøy boat, 100 CE



Kvalsund boat, 700 CE

5 Most infamous Viking raids

01 Lindisfarne, 793 CE

Perhaps the most notorious raid in Viking history, this was the first to take place on English soil, and therefore the most unexpected. It involved the plundering of a remote island monastery in Northumbria, one of the most sacred places in Britain.

02 Rathlin Island, 795 CE

The shorelines of Ireland were rich with monasteries, making them ideal targets for Viking raiders. The first recorded Irish raid was on Rathlin Island, where a monastery was plundered and burned.

03 Martyrs Bay, 806 CE

The wealthy monastery of Iona in Scotland was victim to a series of Viking attacks, but during the worst raid 68 monks were massacred in Martyrs Bay. By 825, the monastery had been completely abandoned.

04 Seville, 844 CE

The first raid in Spain for which there is definite evidence took place in Seville and the city was held for several weeks. However, the Vikings suffered severe losses, and they only escaped by ransoming their prisoners.

05 The Siege of Paris, 885-6 CE

Hundreds of ships, and possibly tens of thousands of men, arrived at the gates of Paris in late November 885 in an attempt to raid the city. Their efforts to break through the walls failed, but the emperor allowed them to sail further down the Seine.

Viking conquests

Thanks to their po werful longships and advanced navigation skills, Vikings were able to establish an empire of trade and colonies

Greenland
The first Norse settlement in Greenland was founded by Erik the Red, after he was exiled from Iceland for committing a murder.

L'Anse aux Meadows
This was the site of a failed Viking settlement. According to Norse sagas, they were driven away by the indigenous people, who they called Skrælings.

Iceland
Legend has it that Iceland was first discovered by a Viking explorer who had sailed off-course, and it was colonised shortly after.

Ireland
Ireland was devastated by over two centuries of raids and attacks, but Viking settlers were eventually absorbed into Irish culture.

Seville
Viking warriors captured the city of Seville in Spain before being forced back out by the Moors.

Illustrations by Stian Dahlslett **www.dahlslett.com**

What happened to the Vikings?

By the early 12th century, the age of the Vikings had come to an end. In Britain, the events leading up to the Battle of Hastings in 1066 saw the Viking king Harald Hardrada defeated, and the city of Jorvik was later burned to the ground. But what we often forget is that the new king – William the Conqueror – was a descendent of the Vikings, though it would have been hard to tell. Settlers across Europe had become so absorbed into the local populations that they bore little resemblance to the heathens who had first arrived there; the Old Norse language was left behind, save for a few words, as was the pagan religion. Christian missionaries set sail for Scandinavia, slowly converting the remaining pagans and as a result Viking raids petered out. When the raids eventually stopped, the rest of Europe no longer saw the Norsemen as Vikings, but Danes, Swedes, Norwegians and Icelanders.

Harald Hardrada was killed in the Battle of Stamford Bridge, just a few weeks before the Battle of Hastings

Bulgar
This was a flourishing market on the Volga river, where the Vikings were able to trade goods from the Far East.

Kiev
In 882, the Viking leader Oleg seized the city of Kiev. It became the centre of the trade route between Constantinople and the west.

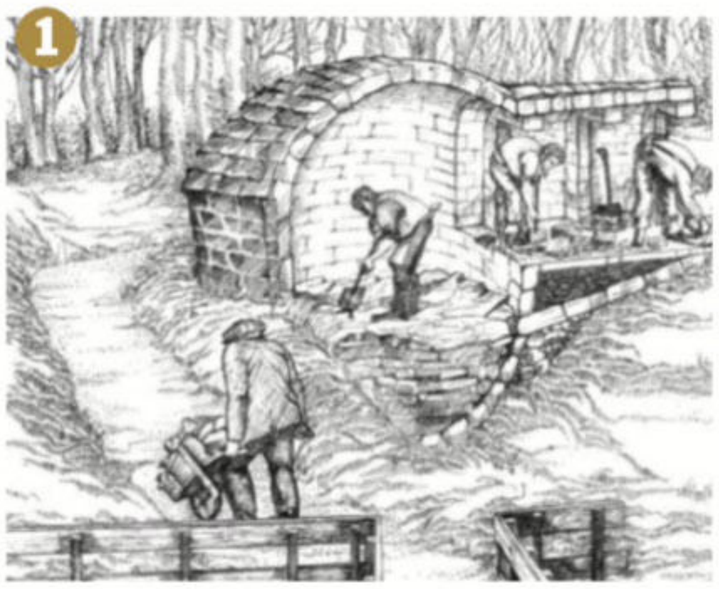
Italy
A powerful Viking chieftain called Björn Ironside led an invasion of Pisa and Luna, but the majority of his fleet was later destroyed by the Saracens.

Constantinople
Attracted by the riches that the heart of the Byzantine Empire offered, the Vikings waged war, establishing a number of trade treaties as a result.

Baghdad
Vikings followed rivers down through Europe to the Caspian Sea, continuing to Baghdad on camel caravans where they traded goods like fur, tusks and seal fat.

Fridges through the ages

The ingenious methods humans have used to keep food cool



1700 BCE

1 Ice houses
Zimri-Lim, the king of Mari in Syria, ordered the construction of an ice house, which no previous king had ever built. Ice was collected from nearby mountains and stored in pits in the ground so it would remain cool. Ice houses were still used in the UK and USA right up until the 20th century.

1400 BCE

2 Evaporative coolers
Without access to ice, ancient Egyptians stored wine in earthenware jars called amphorae. They would leave the amphora outside during the cool nights, and slaves would sprinkle them with water. The cold wind caused the water to evaporate, slowly cooling the wine inside.

400 BCE

3 Yakhchal
To store ice in the desert, Persians built mud brick domes. In winter, water was led into channels underground and left to freeze. The ice was moved into the yakhchal, which had two parts: the dome and a pit. Warm air rose, leaving cold air underground to chill the ice.

1805

4 Ice box
The ice harvesting industry took off in the 19th century and it became common for people to have an ice box in their home. They were made of wood, lined with metal and insulated with straw or cork. Ice was delivered every few days and placed inside to keep food from spoiling.

1748

5 Artificial refrigeration
Artificial refrigeration was first demonstrated by Scottish chemist William Cullen, but in 1834 US inventor Jacob Perkins built the first refrigerating machine. However, early fridges were expensive and used toxic gases as refrigerants, making any faulty leaks deadly.

1920s

6 Domestic fridges
Early domestic fridges were still dangerous and cost more than a car, but soon a much safer refrigerant chemical called Freon was developed and the fridge soon became a common feature of most kitchens. Over the next few decades, they became even cheaper and more eco-friendly.

William Cullen

Jacob Perkins

Learn more

Find out more about the history of the fridge and discover how refrigeration has changed the world in *Chilled* by Tom Jackson. The book is published by Bloomsbury and will be available from 16 July for £16.99 ($27).

The first keys

Unlocking the secrets of keys throughout history

One of the earliest known examples of a key and lock system was used in Egypt 4,000 years ago. The simple mechanism consisted of a wooden bolt secured to the door, with several wooden pins gripping it into position. The wooden key resembled a toothbrush in shape and featured pegs at the end that, when inserted into the lock, pushed the pins upwards to release the bolt. However, this offered little security, as any key could open any lock. To solve this problem, the Romans developed the warded lock, often made of iron or bronze. Notches and grooves called wards were cut into the keyhole, so that only keys cut with corresponding notches and grooves could fit into it. Warded locks still weren't particularly secure though, as instruments could be fashioned to fit the wards and pick the lock, but they still remained in use for centuries. After a few more attempts at developing a more secure system, it wasn't until the 1800s that American Linus Yale and his son Linus Yale Jr developed the spring-driven pin-tumbler lock that is still commonly used today.

The bronze and iron warded lock system was used throughout the Middle Ages

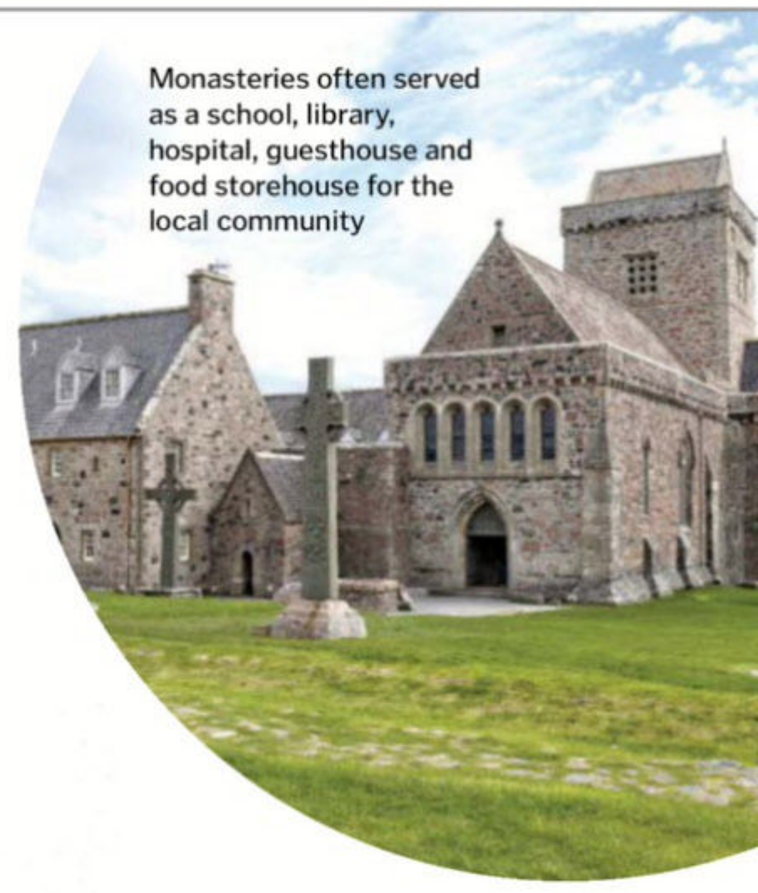
Anatomy of a medieval monk

How to become a holy man in the Middle Ages

Medieval monks were men who dedicated their lives to serving God and their local community, and would live most of their lives within the walls of a monastery. Any man could become a monk, no matter what their social status, and some parents would even hand their child over to a monastery to be educated and bought up to perform religious duties.

However, an adult actively seeking to become a monk would first have to complete a one-month postulancy period before receiving training as a novice for one year. They would then take their simple vows, and after a further four years of service, take their final, or solemn, vows. These differed depending on which religious order the monk belonged to, but usually included the three Benedictine vows: the vow of poverty, meaning they had to give up all their belongings; the vow of chastity, meaning they could never marry; and the vow of obedience, meaning they had to follow the rules of the monastery.

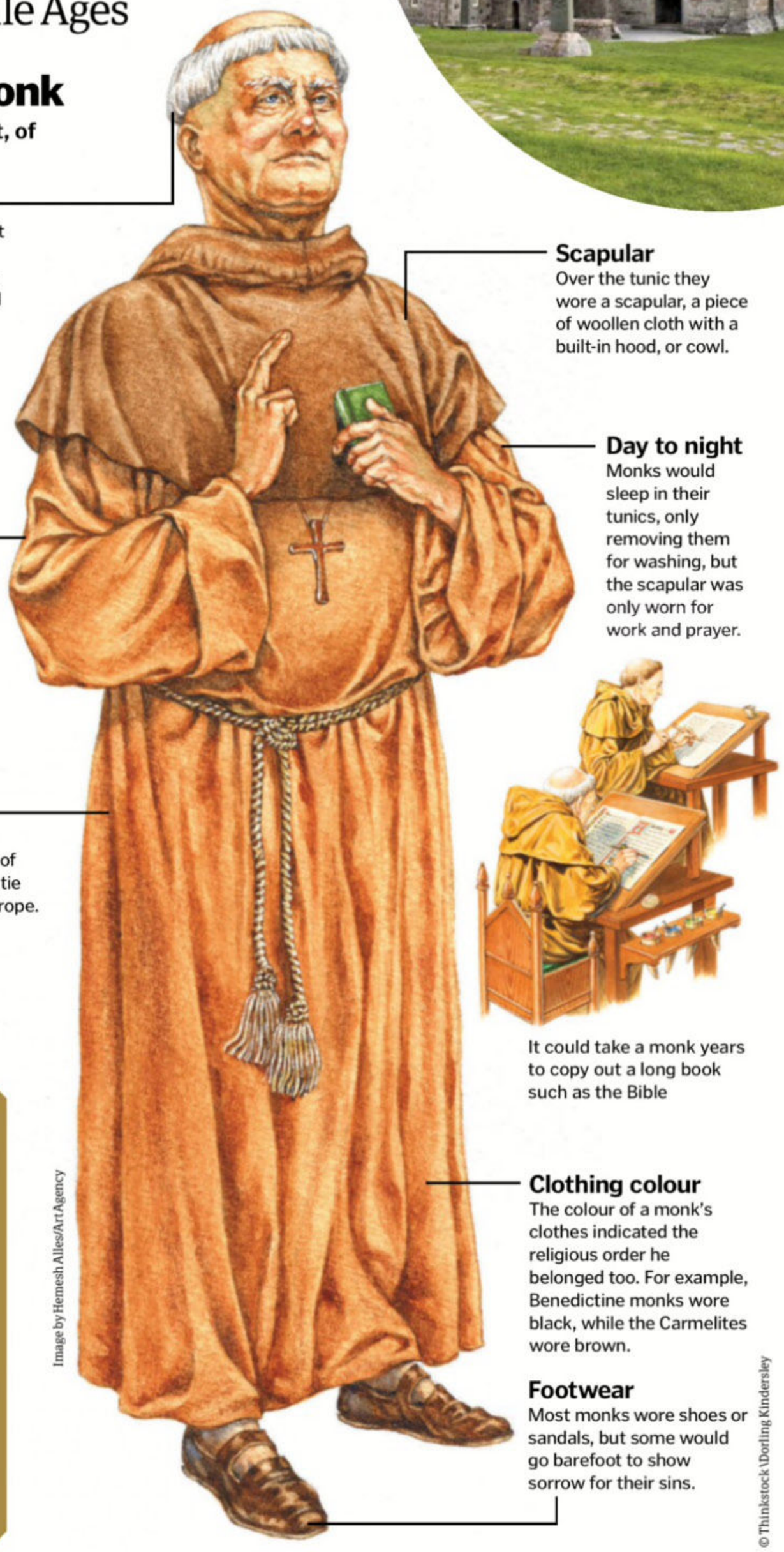
These rules were made by the abbot, the monk in charge of the monastery, and involved a strict routine of work and prayer. Each monastery was also seen as an important part of the local community, as the monks would provide medical care for the sick and hospitality for travellers and the poor. In return, local families would pay one tenth of their yearly earnings to the Church, known as tithes, meaning some monasteries became incredibly wealthy.



Monasteries often served as a school, library, hospital, guesthouse and food storehouse for the local community

Life as a monk

The clothing, or habit, of a typical monk



Hairstyle
To show their commitment to the Church, monks had their scalp shaved, leaving a small strip of hair around the head in a practice known as tonsure.

Scapular
Over the tunic they wore a scapular, a piece of woollen cloth with a built-in hood, or cowl.

Day to night
Monks would sleep in their tunics, only removing them for washing, but the scapular was only worn for work and prayer.

Hair shirt
Some monks would impose suffering on themselves by wearing itchy shirts made of hair underneath their clothes.

Tunic
Each monk was given a floor-length tunic made of wool, which they would tie around their waist with rope.

It could take a monk years to copy out a long book such as the Bible

Clothing colour
The colour of a monk's clothes indicated the religious order he belonged too. For example, Benedictine monks wore black, while the Carmelites wore brown.

Footwear
Most monks wore shoes or sandals, but some would go barefoot to show sorrow for their sins.

Image by Hemesh Alles/Art Agency

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A strict schedule

The daily life of a monk centred around prayer. The main prayer book used was the Book of Hours, which was divided into eight sections, intended to be read at specific times of day. When they weren't praying, the monks were required to carry out manual labour and chores to aid the running of the monastery. Their work depended on their personal interests and skills but could include farming the surrounding land, making wine, cooking the food, washing the clothes, copying manuscripts to preserve them for future generations and educating novice monks.

4:30	Get up
5:00	Lauds prayer service
6:00	Prime prayer service
6:30	Breakfast
9:00	Terce prayer service
9:30	Work
12:00	Sext prayer service
13:00	Midday meal
13:30	Private reading and prayer
15:00	Nones prayer service
15:30	Work
17:00	Vespers prayer service
18:00	Compline prayer service
18:30	Bed time
02:00	Matins prayer service

THE OTHER SENSES

Discover the ten senses you never knew you had

The five classic human senses get all of the attention, so it might surprise you to know that there are several more senses working quietly in the background. Take something as simple as sitting down to eat your dinner. All five senses are active, taking in the sight and smell of the food on your plate, the taste and feel as you put it into your mouth, and the sound as you chew, but without your other senses, the experience would not be the same.

The simple act of sitting at the table and getting the food from the plate to your mouth is a sensory feat. You can't keep an eye on your limbs all the time, so the positions of your joints and the tension on your muscles is constantly measured, enabling you to eat without having to closely watch what you are doing. In order to stay balanced as you reach across the table, sensory information is quietly gathered by specialist structures in the inner ear.

Once the food is inside your mouth, one set of sensors provide information about the temperature, and another set of specialist nerves called nociceptors quickly alert you if the mouthful is dangerously hot or cold. At the same time, your blood and the fluid surrounding your central nervous system are monitored to make sure that levels of carbon dioxide and oxygen remain within normal limits, and your breathing rate is subconsciously adjusted.

As your stomach starts to fill up, stretch sensors feed back to the brain, turning down the signals that are telling you to keep eating, and when the part-digested food starts to hit your small intestine, sensors trigger the production of a hormone that flicks the switch telling you that you have had enough. The build-up of waste products is also closely monitored, and long after your meal is completed, sensors will alert you when it is time to get rid of anything that is left over.

So while the traditional five senses are the ones that we rely on most in our conscious interactions with the world around us, there are several more that work quietly in the background as we go about our daily lives.

DID YOU KNOW? *Otolith is ancient Greek for 'ear stone' and describes the gravity-detecting crystals of calcium inside the ear*

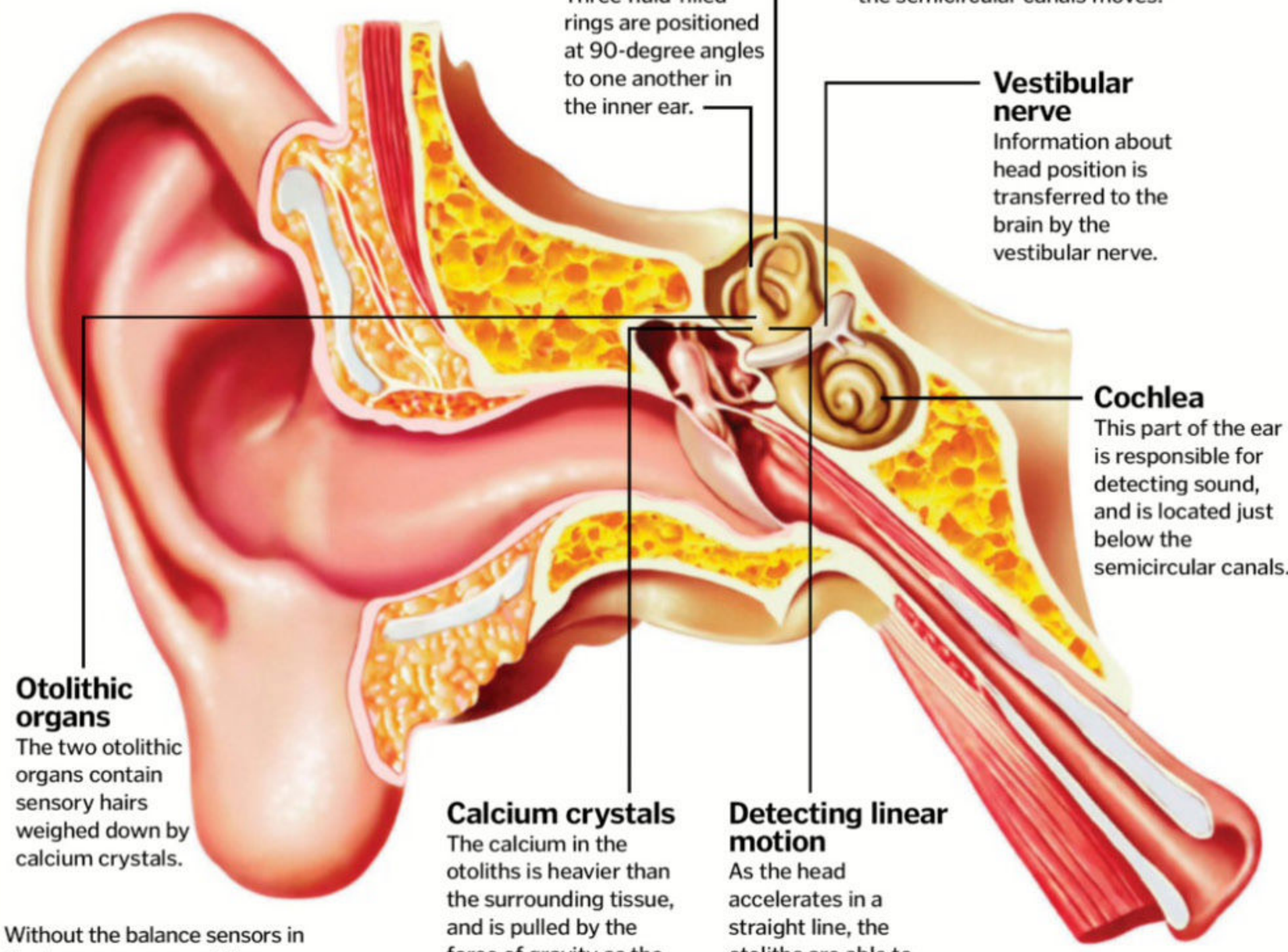
The brain uses a combination of signals from the eyes, ears, joints and muscles to maintain balance

Balance (equilibrioception)

Our sense of balance is handled by the vestibular system in the inner ear, and provides vital feedback about head position and movement. Inside the ear there are three semicircular canals; each is filled with fluid. At one end of each canal is a bulge supporting a series of sensitive hairs. As you move your head, the fluid moves too, bending the tiny hairs and sending information about head rotation to the brain. There are also two organs called otoliths on each side of the head. These contain sensory hairs weighed down by calcium crystals that help to tell which way is up.

The sense of balance

The inner ear contains specialised structures that detect head movements



Semicircular canals
Three fluid-filled rings are positioned at 90-degree angles to one another in the inner ear.

Detecting head rotation
As the head rotates, the fluid in the semicircular canals moves.

Vestibular nerve
Information about head position is transferred to the brain by the vestibular nerve.

Cochlea
This part of the ear is responsible for detecting sound, and is located just below the semicircular canals.

Otolithic organs
The two otolithic organs contain sensory hairs weighed down by calcium crystals.

Calcium crystals
The calcium in the otoliths is heavier than the surrounding tissue, and is pulled by the force of gravity as the head moves.

Detecting linear motion
As the head accelerates in a straight line, the otoliths are able to detect the movement.

Without the balance sensors in the inner ear, we would be constantly dizzy and disorientated

"The positions of your joints and the tension on your muscles is constantly measured"

Without proprioception, you wouldn't be able to touch your nose with your eyes closed

Keeping track

Specialised fibres inside the muscle are able to detect stretch and movement

Damage limitation
The nerve signals are transmitted rapidly, preventing the muscle from being overstretched.

Movement tracking
As the muscle stretches, the nerve endings are triggered, feeding back information about muscle length and speed of movement.

Wrapped nerve cells
The sensory muscle fibres are wrapped in a coil of branching nerve endings.

Extrafusal myocyte
The main muscle fibres are responsible for contraction, controlled by incoming nerve signals.

Intrafusal myocyte
In-between the main muscle fibres are specialised sensory fibres. As the muscle stretches or contracts, the sensory fibres also change length.

Movement (proprioception)

Even the simplest movements would be a challenge without this sense; proprioception allows us to keep track of the position of our bodies in space without looking. This enables us to make the tiny adjustments that keep us from falling over when we are standing still, helps us to judge the distance each time we take a step, and allows us to coordinate complex movements like riding a bike or playing the piano. The receptors responsible are found in the joints, muscles and skin, and help to relay information about the angle and position of each joint, and the tension on our tendons and muscles, providing the brain with constant feedback.

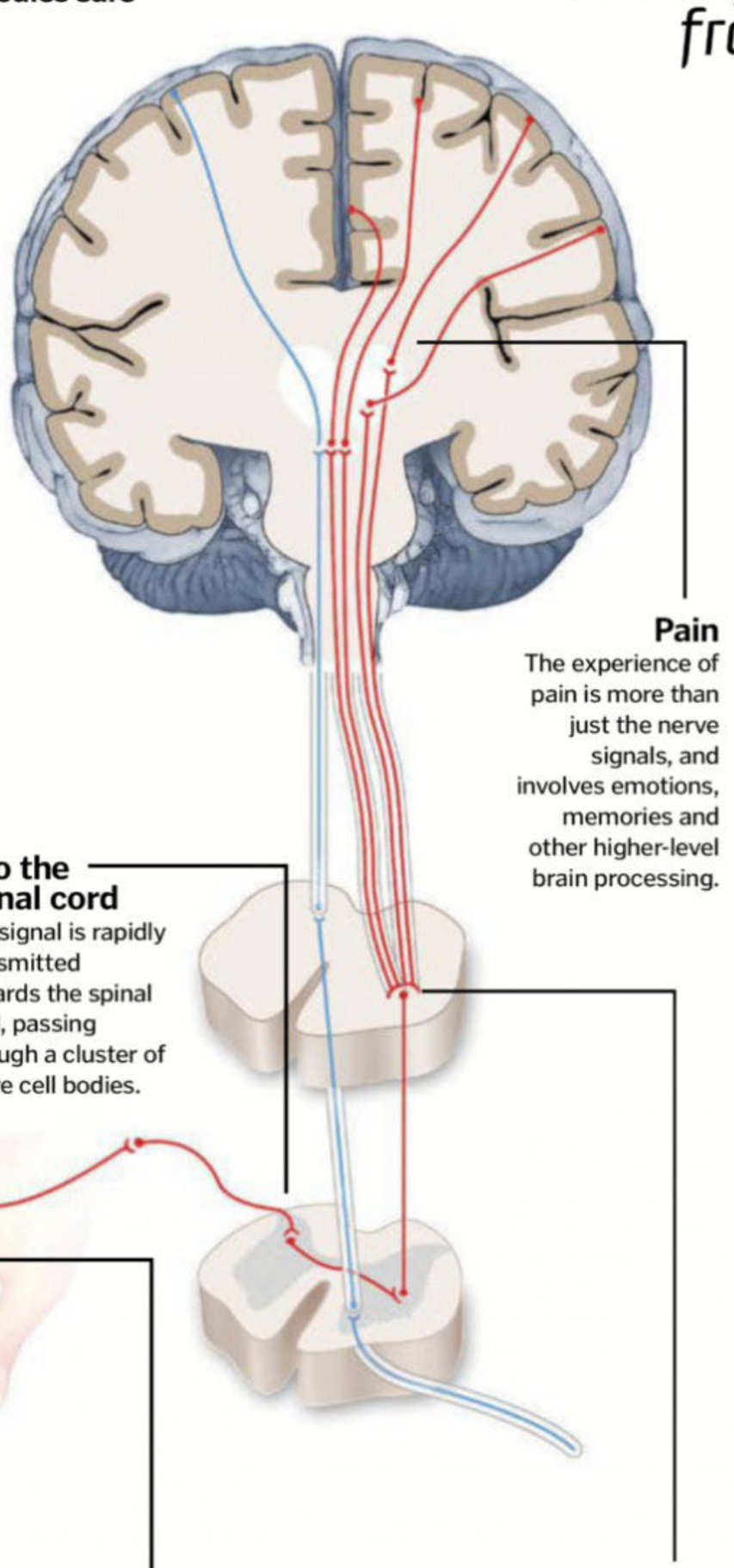
Pain (nociception)

This sense allows us to tell the difference between a harmless touch and potential damage

Specialised nerve endings called nociceptors are found in the skin and organs. Unlike normal sensory nerves, these are not activated by low-level stimulation, and instead wait until the temperature, pressure or level of a toxic substance is enough to cause the body harm. Activation of these nerves can trigger a swift withdrawal reflex, prompting us to move away from the harmful stimulus, and in the long term it acts as a deterrent, teaching us to avoid whatever it was that caused the unpleasant sensation in the first place. The ability to sense damaging stimuli is different from the feeling of pain, and the sensation that we are all familiar with involves a significant amount of further processing in the brain.

How we feel pain

Detecting damage helps to keep our bodies safe



Pain
The experience of pain is more than just the nerve signals, and involves emotions, memories and other higher-level brain processing.

Into the spinal cord
The signal is rapidly transmitted towards the spinal cord, passing through a cluster of nerve cell bodies.

Pain receptor
Nociceptors are only activated if tissue damage is imminent, alerting the body to potential danger.

Heat
Some nerves respond specifically to heat, becoming active at temperatures above 40-45 degrees Celsius (104-113 degrees Fahrenheit).

Cold
Other nerves respond to cold temperatures, and start to fire when temperatures drop below five degrees Celsius (41 degrees Fahrenheit).

Pressure
Some nociceptors respond to pressure, triggering when parts of the body are dangerously compressed.

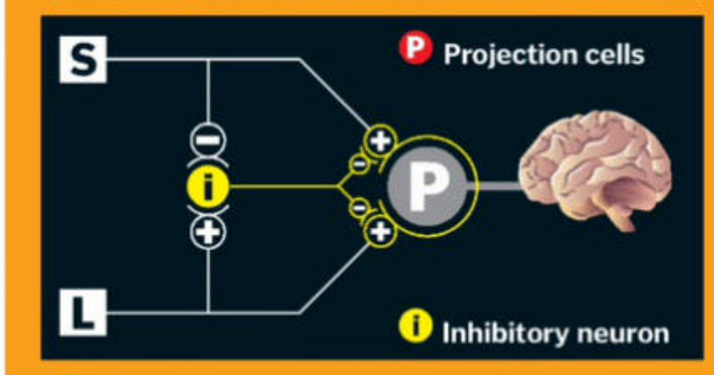
Chemical
Some nociceptors respond to chemical signals of tissue damage, like the presence of acid, or the lack of oxygen.

Towards the brain
The incoming signal can induce a rapid withdrawal reflex just by reaching the spinal cord, but the feeling of pain relies on signals travelling onwards to the brain.

"The ability to sense damaging stimuli is different from the feeling of pain"

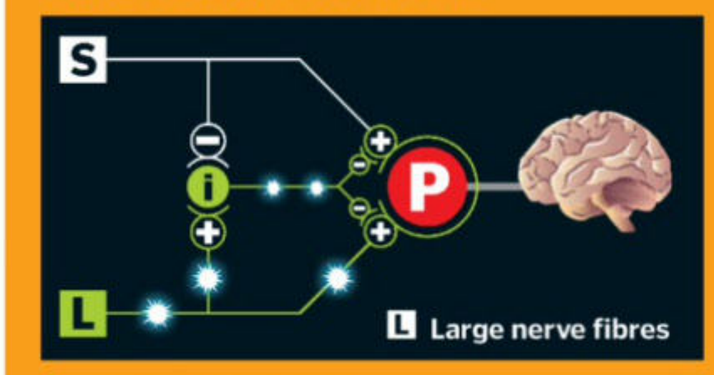
Numbing the pain

Have you ever put your finger in your mouth after shutting it in a door, or grabbed hold of your foot after stubbing your toe? Incoming signals from our other senses can switch off pain signals, preventing some of them from reaching the brain.



Pain gate

Nociceptive (pain-detecting) nerves send their signals towards the spinal cord before they go on to the brain, but in order to reach the brain they have to travel through a biological gate.



Inhibition of pain

Touch-sensitive nerves pass their messages through the same region as the pain signals. These nerve cells are larger and faster, and are able to close the gate, overriding the pain signals.

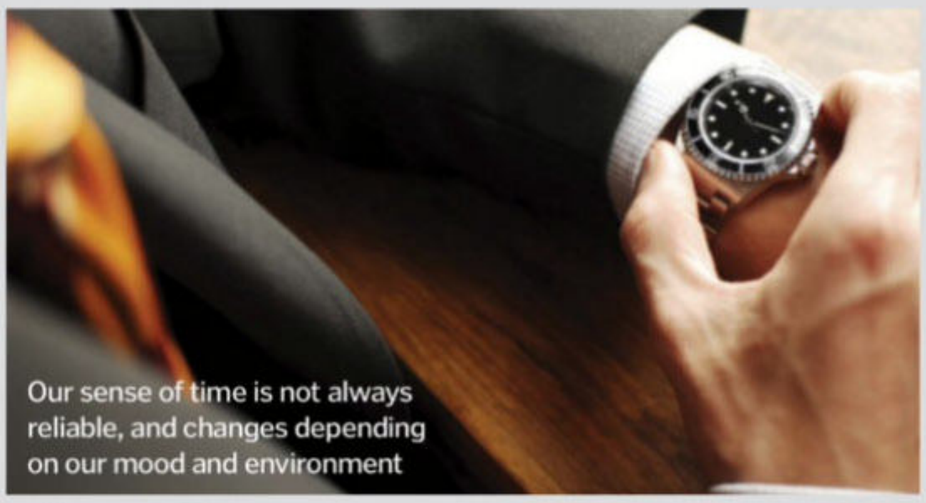
Pain signal

Without the input from the large nerve fibres, the gate is opened. This allows pain messages travelling along the smaller nerve fibres to pass through the spinal cord and onwards towards the brain.

Time (Chronoception)

Internal clocks help us to keep track of time

Even without a watch, we have a sense of the passage of time, but our body clock is not like any normal timepiece. The suprachiasmatic nucleus in the brain is the master clock, and it governs our daily cycle, or circadian rhythm. This 24-hour clock controls daily peaks and troughs in our hormone levels, influencing many behaviours, from eating to sleeping. For shorter tasks, scientists think that we might have several internal stopwatches keeping time inside our brains. As yet, the parts of the brain responsible for keeping these rhythms have not been discovered.



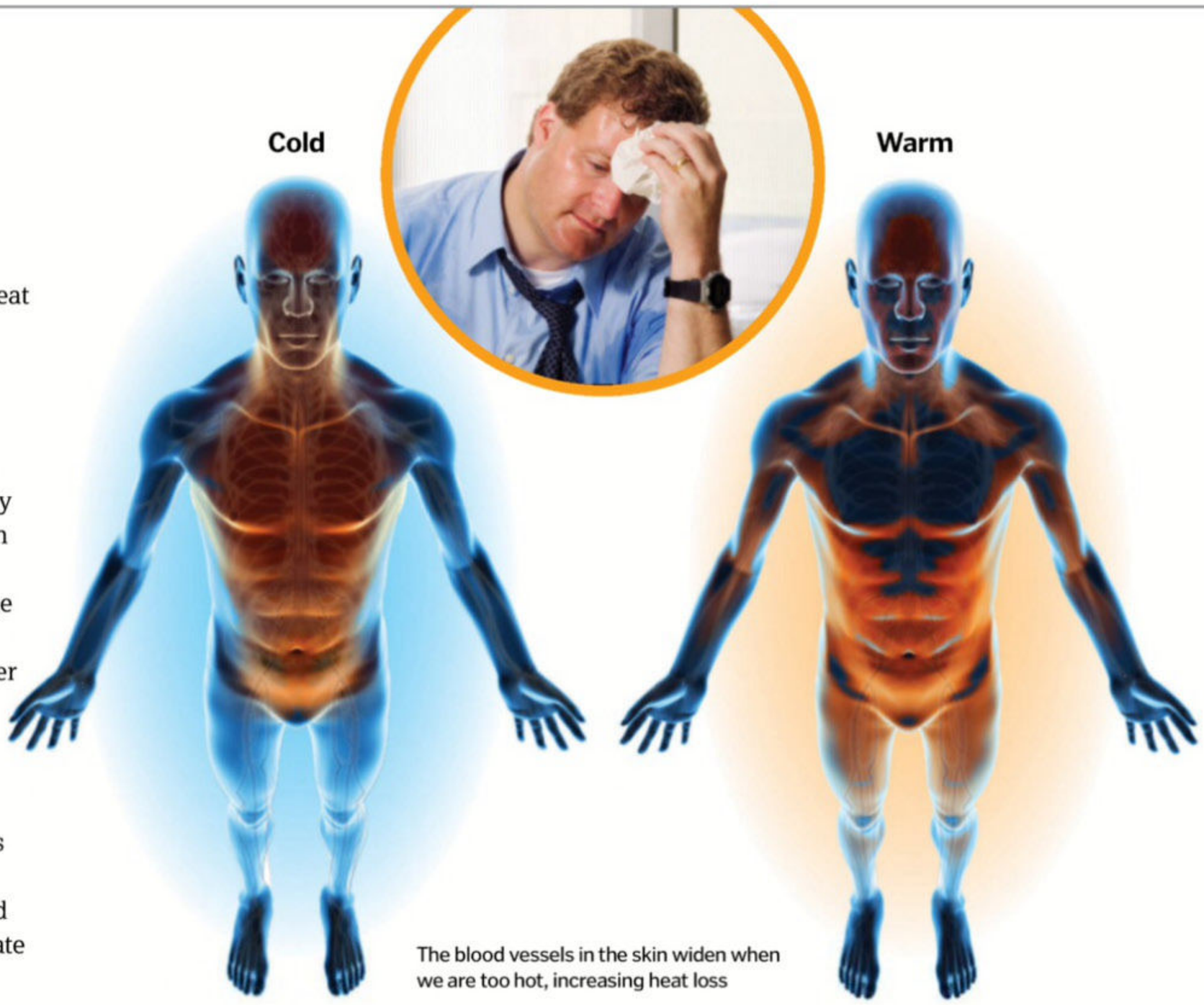
Our sense of time is not always reliable, and changes depending on our mood and environment

Temperature (thermoception)

An internal thermostat keeps our body temperature at a constant 37°C (98.6°F)

It is crucial for our bodies to be able to detect heat and cold, firstly to ensure that our internal organs are kept at the right temperature to function properly, and secondly to prevent us being damaged by extremes. We are able to detect the temperature of our extremities by a series of nerves in the skin, while our core body temperature is monitored by a part of the brain known as the hypothalamus.

As warm-blooded animals, we generate huge amounts of heat as we burn sugars to release energy. This helps to keep us warm, but in order to maintain a constant temperature, adjustments need to be made continually to make up for changes in the environment or changes in our level of activity. For immediate changes in body temperature, the brain orders the body to shiver or sweat, and for more long-term regulation, the production of thyroid hormone is ramped up or down, altering the rate at which we burn sugars and generate heat.



The blood vessels in the skin widen when we are too hot, increasing heat loss

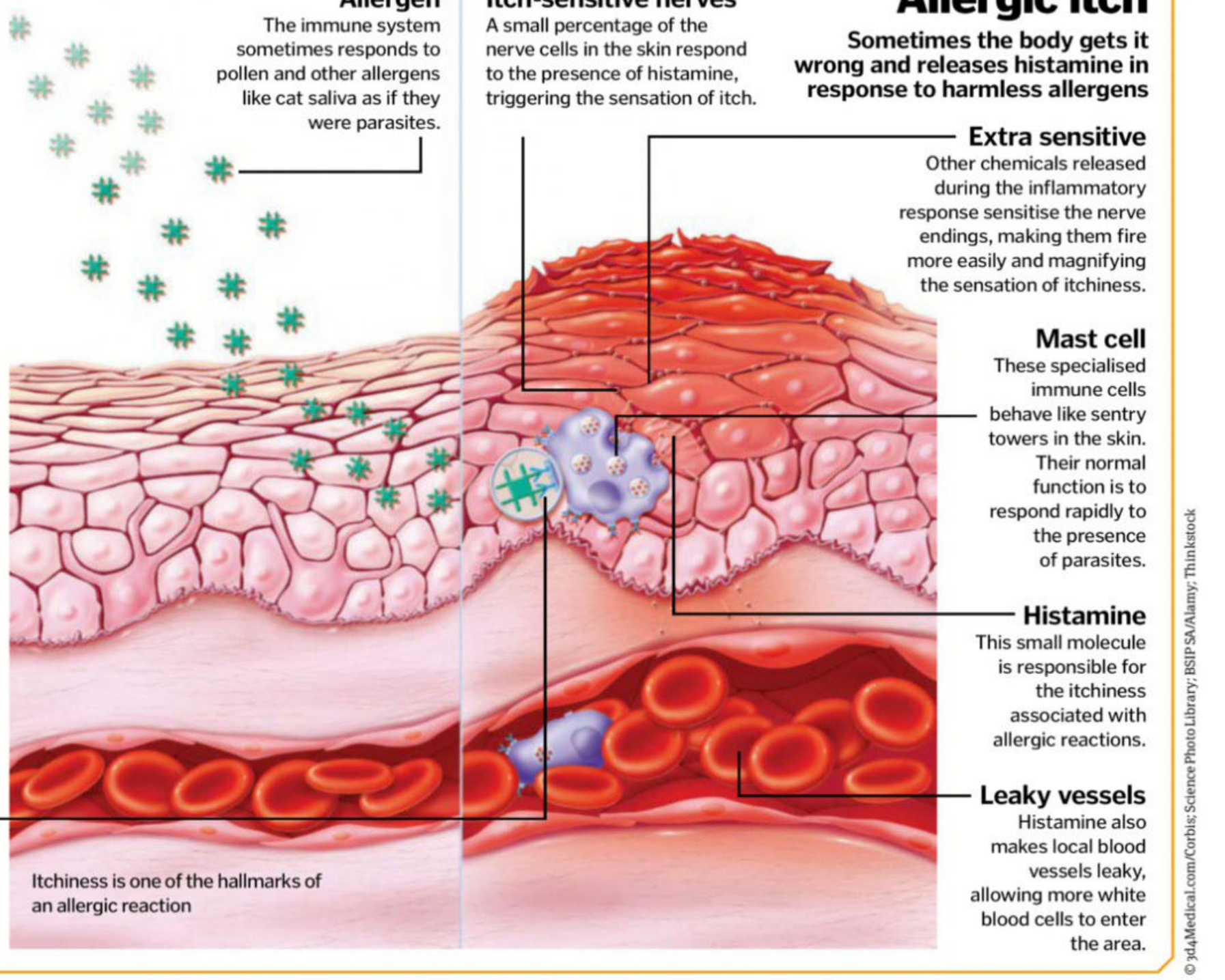
Itchiness

This unusual sensation is closely related to pain

Itchiness is the body's way of alerting us to parasites and irritants. It prompts a reflex scratch response, which scientists think is to draw our attention to that area of the body so any irritant can be eliminated. The exact science of itching is still unclear, but one of the most well studied culprits is a molecule known as histamine. Parasites like biting insects and worms often produce chemicals known as proteases, which help them to break through the barrier of the skin. These proteases trigger white blood cells to release histamine, which in turn activates our body's itch-sensitive nerve cells.

Allergic itch

Sometimes the body gets it wrong and releases histamine in response to harmless allergens



Itchiness is one of the hallmarks of an allergic reaction

Internal sensors

Specialist sensory cells inside the body supply the brain with information about vital systems

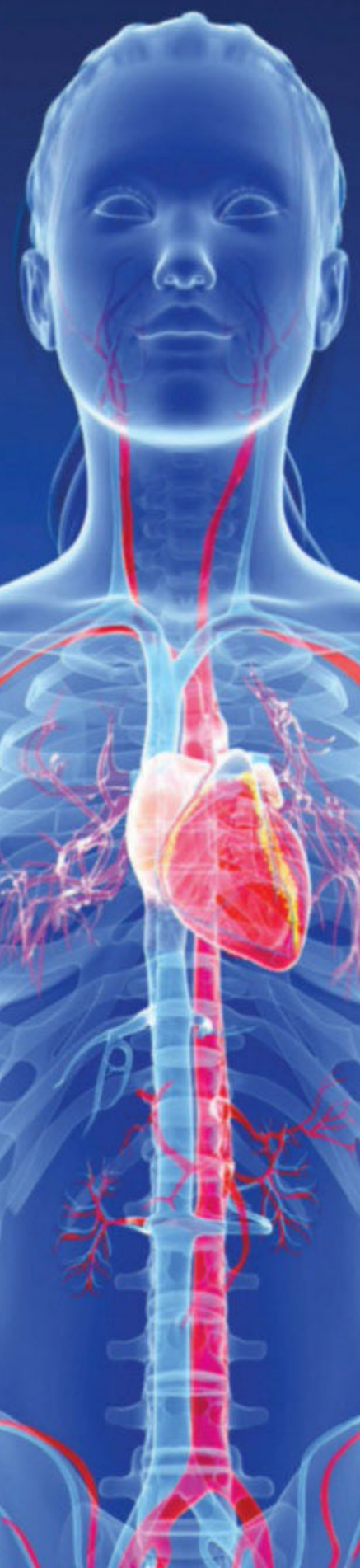
We are all familiar with the senses that allow us to interact with our external environment, but behind the scenes, we need to constantly keep track of events happening on the inside. If we didn't, our tissues would quickly run out of fuel and oxygen, and waste products would start to build up. The state of the body is constantly monitored by specialised sensory cells in the brain and organ systems, ensuring that any imbalances are quickly noticed and corrected, helping to ensure that the supply of food, water, and oxygen always meets the demand.

Thirst

Sensing the water level in our bodies prevents dangerous dehydration

The ability to detect when we need to drink is crucial for survival. When we don't have enough water, the salts, sugars and proteins inside our bodies become more concentrated, and function starts to decline.

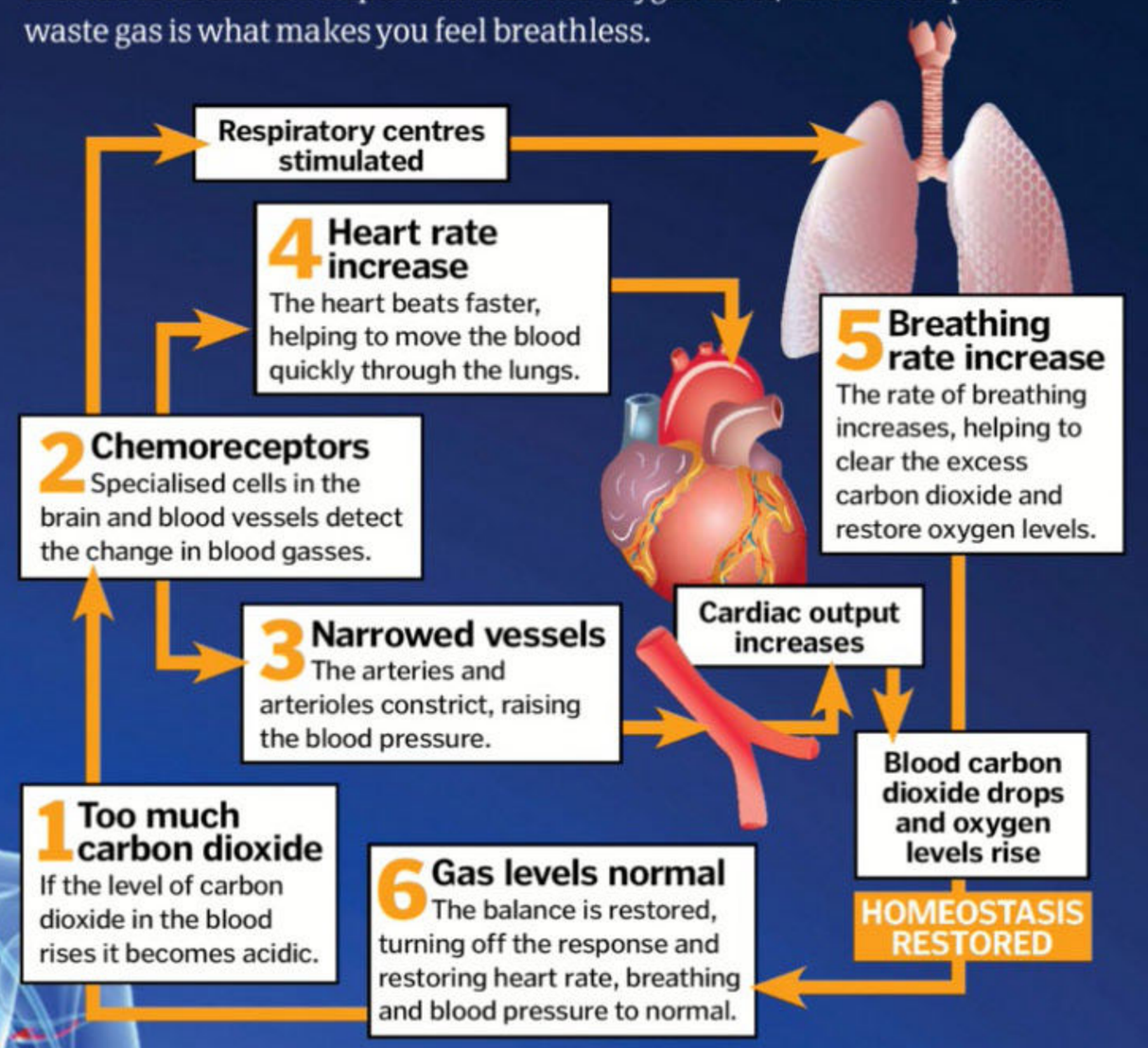
Minute changes in water level are detected by special cells in the brain called osmoreceptors, triggering the feeling of thirst. To prevent further water loss, the body releases a hormone known as vasopressin, which acts on the kidneys to stop water being excreted as urine. A hormone called angiotensin is also produced, making the blood vessels constrict and raising the blood pressure to compensate for the lack of water until more arrives.



Breathing

The ability to sense blood gases helps to keep oxygen and carbon dioxide levels normal

Breathing is controlled by the respiratory centres in the brain. Sensors in this area, along with sensors in the carotid artery and the aorta, detect the levels of gases in the blood and in the fluid that surrounds the brain. The carbon dioxide level is more important than the oxygen level, as a build up of this waste gas is what makes you feel breathless.



Hunger and fullness

Digestive sensors help to prevent us overeating, but they are easy to ignore

The feeling of hunger is controlled by a part of the brain called the hypothalamus. It produces two types of molecules: orexigens, which make you feel hungry; and anorexigens, which make you feel full. The hypothalamus decides which molecules to produce based on information sent by the digestive system.

When you haven't eaten for a while, the top part of the stomach starts to produce a molecule called ghrelin, signalling to the hypothalamus that you need to take in more food. After a meal, stretch receptors in your stomach help to signal that you are full, and when fat and protein start to enter the first part of the small intestine, a molecule called cholecystokinin (CCK) helps to switch the hungry feeling off.

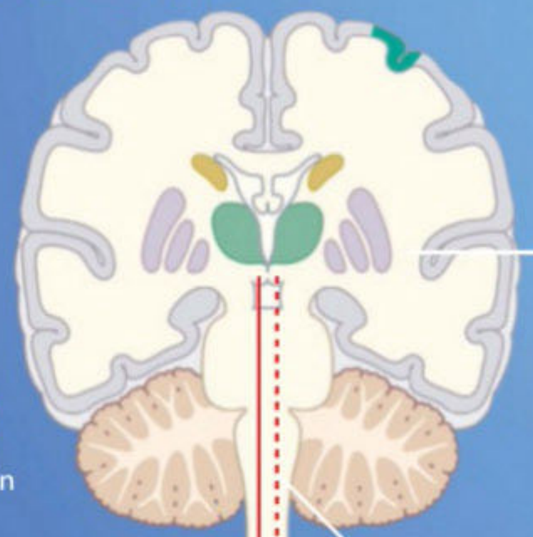
Excretion

Internal sensors help to time the elimination of waste products from the body

It is vital to remove waste products from the body before they start to build up, and there are several internal systems responsible for sensing, processing, and removing waste. Some leave via the lungs, some via the back passage, and some via the bladder.

Control of waste disposal

Bladder emptying is timed using a specialised sense of touch



Voluntary control
The brain has the ability to override the need to go to the toilet, keeping the sphincter firmly closed.

Learning control
During early childhood, nerve connections develop between the spine and the brain, allowing conscious control of urination.

Time to go
When the time is right, the brain removes its control, allowing the bladder to be emptied.

Stretched
The stretch signals provide the brain with information about how urgent the situation is.

Spinal reflex
The act of emptying the bladder is simple, and in infants it is controlled entirely by a reflex requiring no conscious thought.

Rugae
The lining of the bladder is highly folded, allowing it to stretch to many times its original size.

Stretch receptors
Sensory receptors in the walls of the bladder trigger as the lining is stretched.

Fat produces a hormone called leptin, which helps the brain keep track of how much energy is stored

Animal senses

Magnetoreception
This incredible sense allows animals to detect Earth's magnetic field, and is shared by a diverse array of species, from honeybees to sea turtles. Birds may actually be able to see Earth's magnetic field lines by detecting the subtle changes that they make to the light, helping them to navigate in unfamiliar territory.

Electroreception
Muscle movements are powered by electrical impulses, and in water, dissolved ions can transmit the tiny currents. Many aquatic species are able to detect these subtle pulses, alerting them to danger or guiding them to their prey. Sharks, skates and rays have jelly-filled pores known as ampullae of Lorenzini, capable of detecting the slight differences in voltage as a fish swims past.

Heat vision
This specialised sense is used by pit vipers and some other snakes to detect the heat signature given off by their prey. Tiny pits on either side of the snake's head contain thousands of nerve endings that pick up infrared radiation, detecting changes in temperature of just fractions of a degree.

Fluoride explained

How this mineral can protect your pearly whites

Fluoride is a mineral found naturally in water, soil, and in trace amounts in tea and fish. Fluoride can be used as a biochemical agent, but its main use is to help prevent the formation of tooth decay. Around 70 years ago, researchers found that people who drank water containing more fluoride had less tooth decay. This discovery led to the introduction of schemes around the world to add fluoride to water supplies where the level was low.

The substance also became commonplace in many brands of toothpaste. Fluoride protects teeth by encouraging a stronger enamel to form that's more resistant to acid attack. It also reduces plaque bacteria's ability to produce acid – the primary cause of tooth decay. However, it seems that you can have too much of a good thing. Recently in the US, the fluoride in water has been found to cause white splotches on children's teeth – a condition known as dental fluorosis – so the government has lowered fluoride levels. As long as the standard guidelines are followed, fluoride really can be beneficial to your dental health.

Fluoride is used in toothpaste to help fight decay

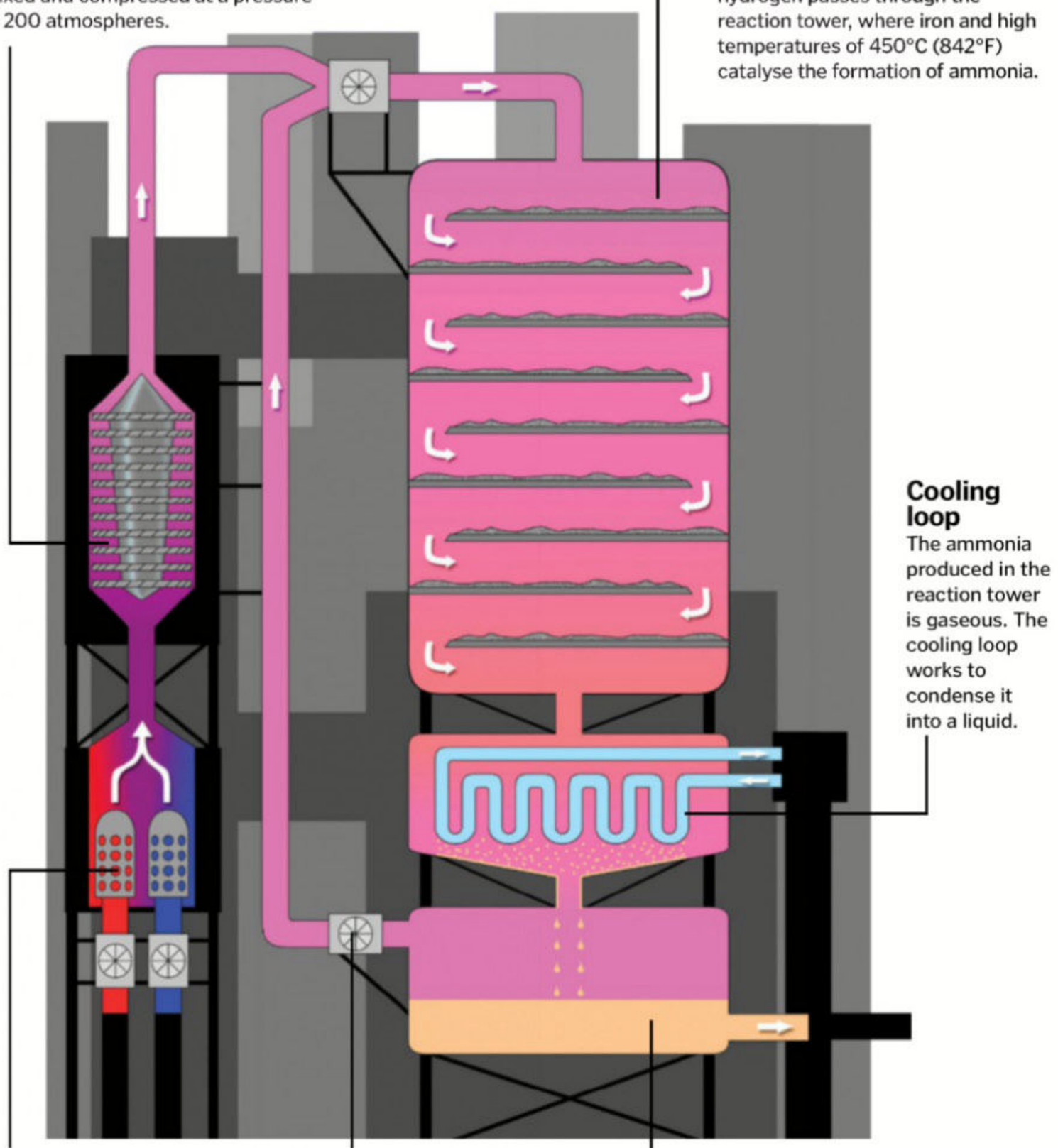
Making fertiliser

How the Haber process helps us grow food

The Haber process is an efficient way of producing ammonia for use in fertilisers and household products. Ammonia has helped to sustain food production for billions of people, but its use in explosives has reportedly resulted in the death of 150 million. It's for this reason that some scientists say ammonia changed the course of the 20th century more than electricity or television.

Industrial production of ammonia

The ins and outs of the Haber process



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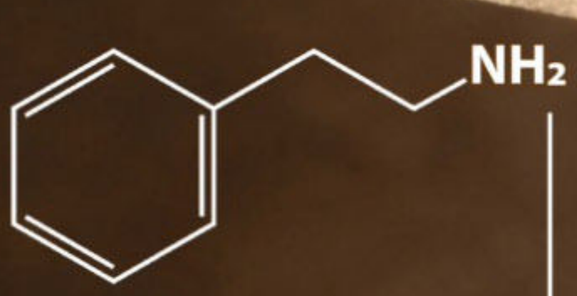
The chemistry of chocolate

Discover why your favourite chocolate bar is so irresistible

There's no doubt that chocolate is one of our favourite indulgences, with over 7.2 million tons of it consumed worldwide each year. What you may not realise is that it's the hundreds of complex chemicals found in chocolate that keep us coming back for more. Not only do they give chocolate its delicious taste and smooth texture, but they also have powerful effects on the human brain to make us feel happy and alert. It's no wonder that the plant genus from which this tasty substance comes from is called theobroma,derived from the Greek for 'food of the gods'.

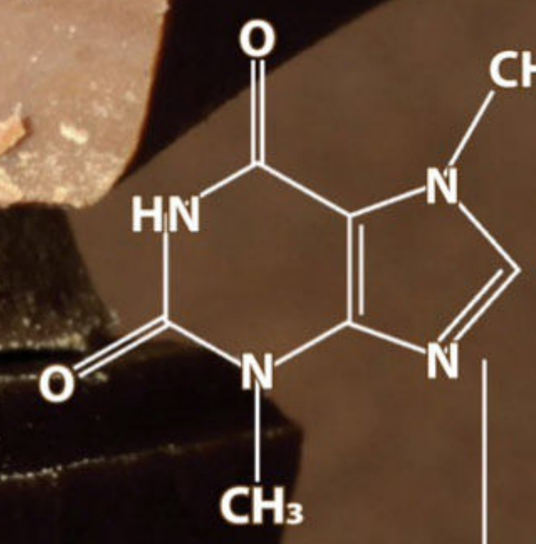
Why your brain loves chocolate

The chemical effects of your favourite sweet treat explained



Pleasurable

As well as being tasty and sweet, chocolate also contains several mood-enhancing chemicals. One such chemical is the amino acid tryptophan, which is used by the brain to produce serotonin, the hormone that boosts your happiness. Another is the alkaloid phenylethylamine (PEA - shown in the diagram here), which encourages the brain to release dopamine, the hormone that creates feelings of pleasure. PEA is responsible for chocolate's reputation as an aphrodisiac, as it also occurs naturally in the brain to release dopamine when you fall in love. However, as there are only very small quantities of tryptophan and PEA in chocolate, there is some debate as to whether they have any effect on the brain at all.



Stimulating

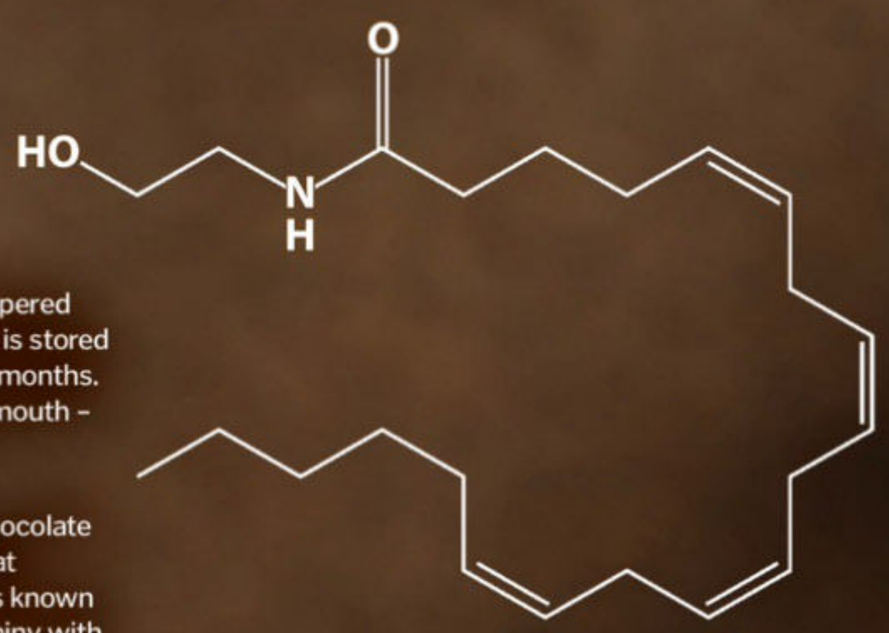
Like coffee beans, cocoa beans contain a small amount of caffeine which is a natural stimulant. This alkaloid helps you feel more alert by blocking the adenosine molecules, responsible for causing drowsiness, from binding to their receptors in your brain. Another alkaloid found in chocolate is theobromine (the structure of which is shown here), which has a similar stimulating effect to caffeine, but is also the reason why chocolate is poisonous to some animals. Theobromine is actually toxic to humans too, but the average adult would have to eat approximately five kilograms (11 pounds) of it to feel the effects. Small mammals have a much lower tolerance and so just 50 grams (1.8 ounces) of chocolate could be lethal to a small dog.

Is chocolate good for you?

Although it is typically considered an unhealthy treat, some chocolate does actually have some health benefits. Cocoa beans are rich in natural antioxidants called flavonols. One such flavonol, called epicatechin, can increase the levels of nitric oxide in your blood to relax your blood vessels. This helps to improve blood flow, lower your blood pressure, and can also prevent atherosclerosis, a condition where the arteries harden after becoming clogged with plaque. Epicatechin can also improve your body's insulin sensitivity, helping to keep your blood sugar levels under control and reduce the risk of diabetes. However, not all chocolate is rich in flavonols. White chocolate is not a good source of these antioxidants as it does not contain cocoa solids, and milk chocolate has a higher proportion of milk and sugar rather than beneficial cocoa. Therefore, dark chocolate is the best option, and the higher the percentage of cocoa solids the better.

Dark chocolate that is over 70% cocoa solids is the healthiest

Tempering helps to create chocolate with a more appealing texture, known as Form V



36.3°C Solid, tempered chocolate is stored at room temperature for four months. Hard and melts slowly in the mouth – some fat blooms – Form VI

33.8°C Molten chocolate is cooled at 31-33°C (88-91°F) in a process known as tempering – smooth and shiny with a good snap – Form V

27.3°C Molten chocolate is cooled at 16-21°C (61-70°F). Firm but doesn't give a good snap – some flat blooms – Form IV

25.5°C Molten chocolate is cooled at 5-10°C (41-50°F). Firm but doesn't give a good snap. Some flat blooms – Form III

23.3°C Molten chocolate is cooled at 2°C (3.6°F) per minute – soft and crumbly with noticeable fat blooms – Form II

17.3°C Molten chocolate is cooled rapidly, ie in the freezer – soft and crumbly with noticeable fat blooms – Form I

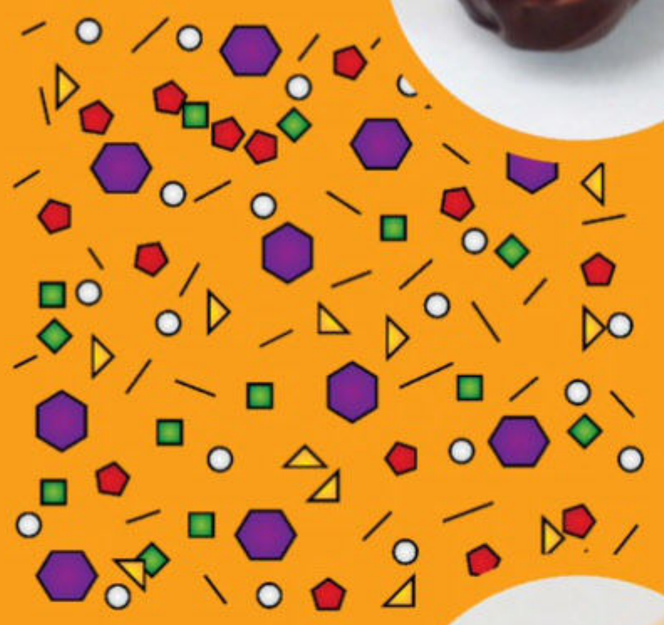
Addictive

If the mood-enhancing chemicals in chocolate don't have you reaching for another piece, then another ingredient might. Anandamide is a cannabinoid neurotransmitter that is found in chocolate and also occurs naturally in the brain. It is very similar to tetrahydrocannibol (THC), the ingredient in marijuana that makes people feel 'high', and therefore creates a similar blissful feeling that we all crave. In addition, chocolate also contains the chemicals N-oleoylethanolamine and N-linoleoylethanolamine, which inhibit the breakdown of anandamide to prolong its effects. Anandamide is only present in chocolate in very small amounts though, so the 'high' you get from it is very mild.

Why is chocolate so tasty?

The glossy shine, satisfying snap and smooth texture of chocolate are the main characteristics that make it so appealing, and they are all achieved through clever chemistry. To form solid chocolate, a liquid cocoa butter mix is cooled so that its fat molecules join together in crystal structures called polymorphs. If the cocoa butter cools and hardens too quickly, the fat molecules form a loose and disordered polymorph that makes the chocolate soft and dull-looking with an unappealing white coating called a fat bloom. To avoid this manufacturers use a technique called tempering, controlling the temperature and rate at which the chocolate cools, to create a tight crystal structure. This particular polymorph is called Form V and gives the chocolate a melting point of around 33.8 degrees Celsius (92.8 degrees Fahrenheit), just slightly cooler than our body temperature (37 degrees Celsius/98.6 degrees Fahrenheit). This means that when you put chocolate into your mouth, it slowly melts over your tongue, creating yet another appealing characteristic. The smooth texture of the melted cocoa butter creates a pleasant 'mouthfeel', a word used by the food industry to describe the way a substance feels in the mouth, and a main contributor to its overall enjoyment.

Soft, dull untempered chocolate



Hard, shiney tempered chocolate

Good chocolate has a tightly packed crystal structure that creates a glossy shine

Physics of hula hooping

How the hoop keeps spinning, if you're doing it right

Although hula hooping comes relatively naturally to most of us, it's actually quite a complex task from a biomechanical viewpoint. In fact, the 2004 Ig Nobel Prize in Physics was awarded for an explanation of hula-hoop dynamics.

The hoop is able to spin due to the momentum created by pushing your hips and stomach back and forth, and by slightly shifting your weight as it spins. The reason the hoop keeps spinning is due to the forward motion of your hips, and not because of any circular movement, which is wrongly implied by the word 'hula' in its name.

This activity has recently gained in popularity due to its potential health benefits. It works the abdominal muscles in your core and studies have shown that using a weighted hoop may help to burn visceral fat, which can be detrimental to the heart.

The forces behind hula hooping

Improve your hula skills by understanding the physics of motion and spin

"This activity has recently gained in popularity due to its potential health benefits"

Friction
Friction from the air and your body will slow the hula hoop down and can result in it falling to the ground.

Centripetal force
Torque is necessary to maintain a centripetal force, which is responsible for keeping the object spinning on its axis.

Parallel oscillation
Successful hula hooping requires a steady, parallel oscillation of the hoop around your waist.

Body torque
By moving your hips forwards and backwards, you exert a force known as torque onto the hula hoop, which causes it to rotate.

Modern material
Modern hula hoops are made of plastic tubing, whereas their ancient counterparts would have been made of willow or similar organic materials.

How does chewing gum work?

Find out how this unusual substance is made and why it doesn't break down when you chew it

The first commercial chewing gum was produced in the 1800s, however the practice of chewing a substance without swallowing it has existed for thousands of years, ranging from tree resin lumps to sweet grasses.

Modern day chewing gum tends to be made up of either synthetic rubber or chicle, both of which give the gum its chewiness. Along with one of these components, chewing gum also contains artificial or natural flavours and some form of sweetener.

The reason why chewing gum doesn't break down after repeated chewing is due to the qualities of its base material. Both chicle and synthetic rubber are extremely malleable; it's possible to mould, stretch and impact them repeatedly without damaging their structure. In this regard, their qualities have more similarities with liquids than solids, and are why they can be chewed for hours on end.

But don't worry – the rumours that chewing gum stays in our digestive system for seven years aren't true. As soon as the body recognises that the synthetic components of chewing gum can't be used, they are sent down the same route as any other waste product.

Modern chewing gum comes in numerous forms, ranging from strips to a pillow-shaped coated pellet, known as dragée gum

Types of scars

Scars are made up of the same proteins as normal skin, so why do they look so different?

Scars are a natural part of the healing process, with most of us having some form of them on our body. The reason why scars look different to normal skin stems from their proteins' composition. Normal skin benefits from a weaved protein structure, whereas the proteins in scars are aligned in one direction. This results in a different appearance compared to normal, healthy skin. Scars are smoother due to a lack of sweat glands and hair follicles, so they can often become itchy.

There are a number of different types of scar that can form. The most common is a flat scar – these tend to initially be dark and raised, but will fade and flatten over time as the scar matures. A hypertrophic scar can be identified by its red appearance and elevated nature. This scar type typically forms when the dermis is damaged, and this can become itchy and painful over time.

Keloid scars are by far the most extreme scar type when compared to the others. Unlike most scars, they extend beyond the confines of the original injury and are formed due to excessive scar tissue being produced. Keloid scars are raised above the surrounding skin, and are hard, shiny and hairless. The reason behind why keloids form is poorly understood, but it is known that people with darker skin tones are more likely to form keloids.

Pitted scars are generally formed from acne or chicken pox, and tend to be numerous in areas where these conditions were prevalent. Scar contractures, meanwhile, usually form after a burn, and are caused by the skin shrinking and tightening. The severity of these kinds of scars can depend on their bodily location; if they form around a joint they can lead to movement being restricted.

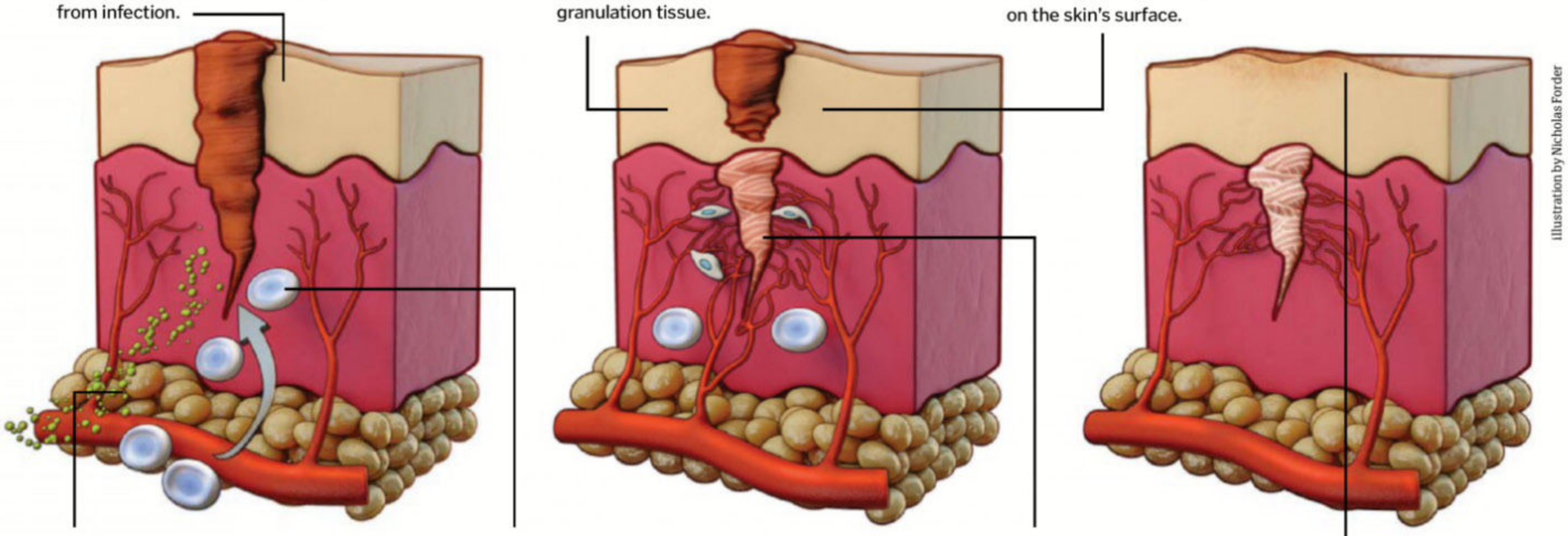
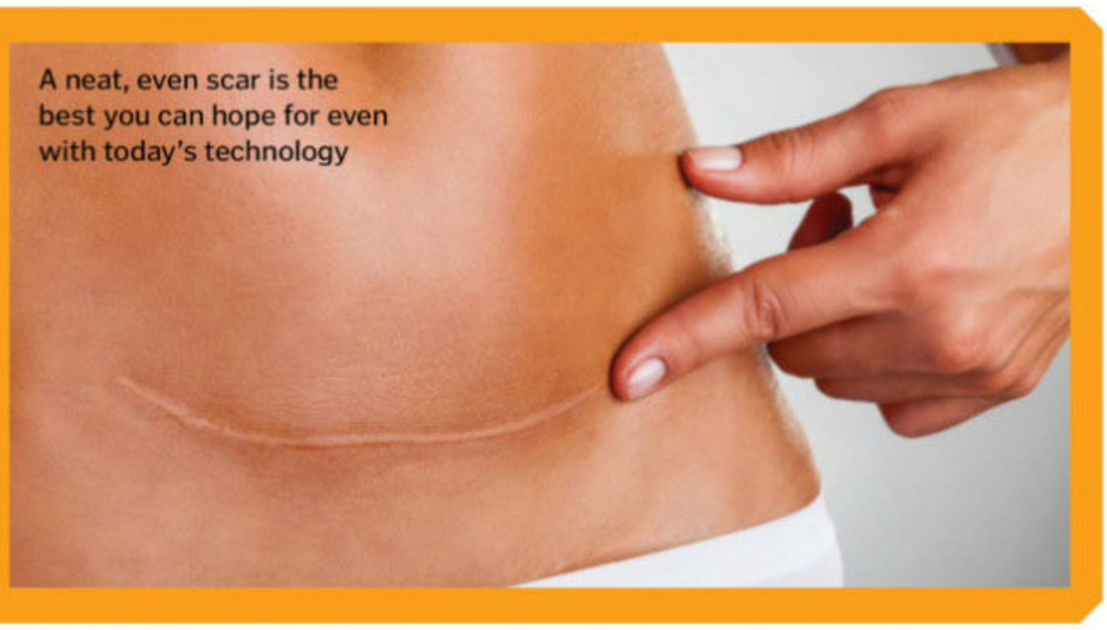


Illustration by Nicholas Forder

Can scars be treated?

Scars cannot be stopped from forming, but there are various treatments available to help reduce their appearance. Silicone gels or sheets have been shown to effectively minimise scar formation and are often used when people have been burnt. These must be applied or worn throughout the scar's maturation phase to maximise their efficacy. Corticosteroid injections can be used to reduce any inflammation (swelling) around the scar and to flatten it as well. A riskier treatment for scars is surgery. This can be used to change the shape of the scar, however it can make scarring worse if unsuccessful.

There are also certain steps that can be taken to help reduce the risk of an unsightly scar forming from an injury. By cleaning dirt and dead tissue away from the wound, you are increasing the chance that the scar will form neatly. It is also vital that you don't pick or scratch the scar, as this will slow down its formation, resulting in a more obvious appearance.



A neat, even scar is the best you can hope for even with today's technology

© Dreamstime

The colour of bubbles

Discover the clever physics that puts on an incredible multicoloured display

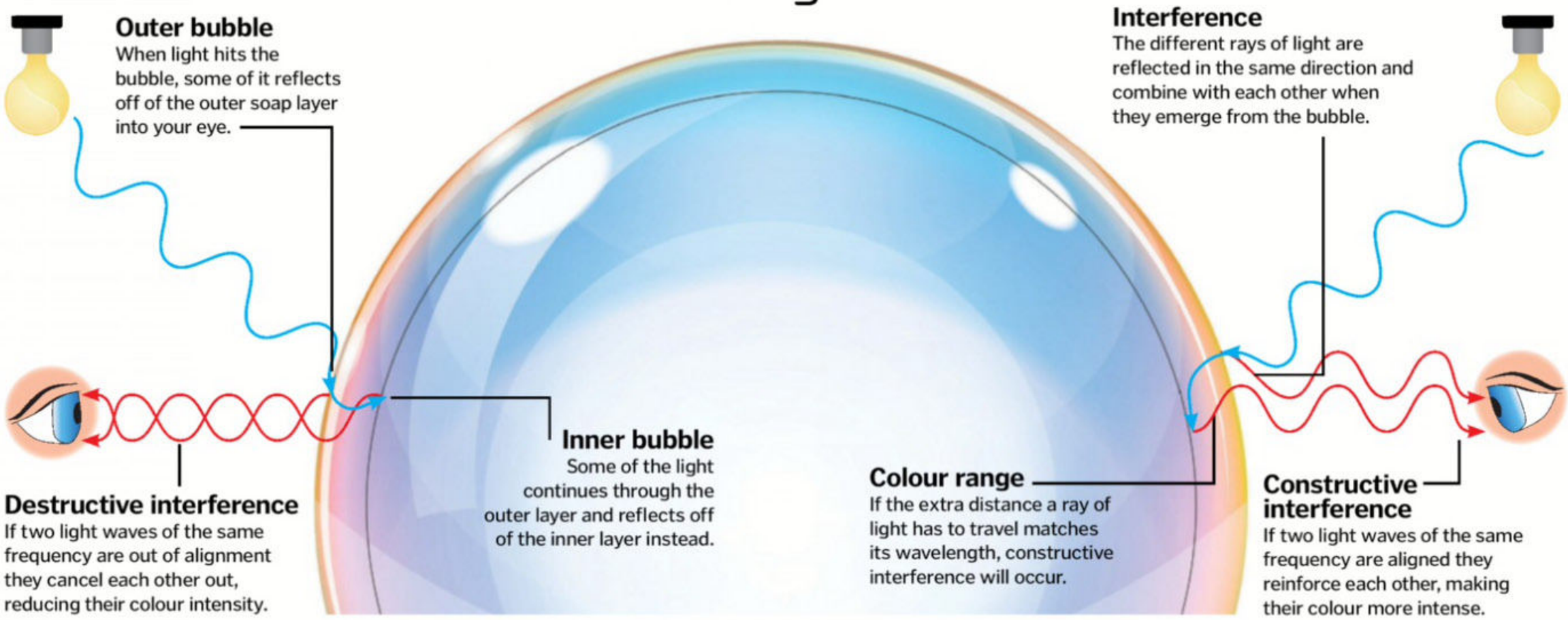
As a bubble moves, light hits it from different angles, causing it to constantly change colour

Bubbles are actually colourless, but their amazing structure and the properties of light make an entire rainbow visible. To understand how this works, you first need to know what a bubble is. The outer film that traps the air inside is made of a thin sheet of water sandwiched between two equally thin layers of soap molecules. The way that light interacts with these layers is what creates the colours you see. Light is made up of light waves that vibrate several times a second. The number of times a wave vibrates is called its frequency or wavelength, and different wavelengths of light have different colours. When light hits a bubble, these individual wavelengths are reflected back into our eyes so that we see them as separate colours. It's this very same process that causes oil slicks floating on water to appear multicoloured and the surface of CDs and DVDs to reflect a rainbow pattern.

Bubbles and light

How bubbles reflect light to produce amazing colours

"The way that light interacts with the bubble's layers is what creates the colours you see"



Colour changing bubbles

The colour a bubble appears to be is dependent on the thickness of its film and the angle from which the light hits it

Thick bubble
If the bubble has a thick film, long red wavelengths of light are reflected out of alignment and cancel each other out, whereas shorter blue wavelengths align to intensify this colour.

Direct light
Light entering the bubble from head on has a shorter distance to travel, causing short blue wavelengths of light to reflect in alignment and intensify.

Thin bubble
As the bubble film gets thinner, progressively shorter wavelengths cancel each other out. A thinning bubble changes from blue to magenta and then yellow.

Angled light
Light entering the bubble from a wide angle has further to travel, so longer wavelengths of light such as yellow are reflected in alignment and intensify.

Colourless
Eventually the bubble's film becomes too thin to align any visible wavelengths of light, so just before it pops all colours are cancelled out and it appears completely colourless.

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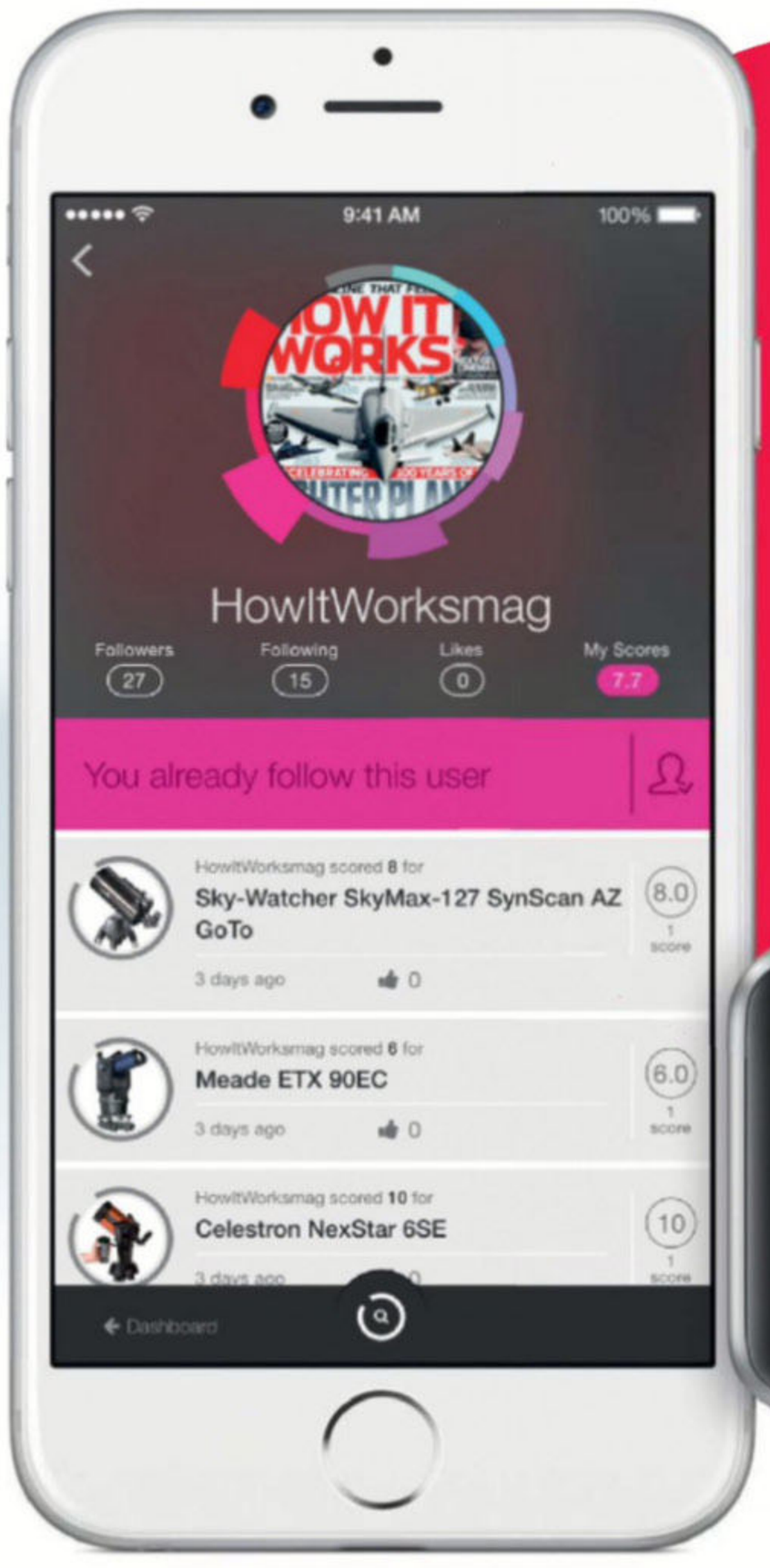

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10 HowItWorksmag scored **10** for Ankylosaurus

9 HowItWorksmag scored **9** for Tyrannosaurus rex

8 HowItWorksmag scored **8** for Triceratops

4 HowItWorksmag scored **4** for Charonosaurus

3 HowItWorksmag scored **3** for Utahraptor

MULTI-DOLLAR

They cost more than three times the average house, so just what's behind the price tag of a modern supercar?

Special interior
Nearly the entire interior lining is made from patented CarbonSkin, which is a carbon fibre derivative, weighing much less than traditional leather.

Gearbox
Lamborghini's own ISR gearbox is seven-speed and double clutch to ensure lightning-quick gear changes.

Big engine
Powering this supercar is a huge naturally aspirated V12 engine with a mammoth displacement of 6.5 litres!

Among the hustle and bustle of today's busy public roads, there's a new age of motoring exotica roaring into prominence. These high-octane hypercars are making headlines chiefly because you'll have to pay the best part of one million dollars just to get one on your drive.

It started with the Bugatti Veyron, which was perhaps the most widely known supercar to cost around the £1 million mark (over $1.5mn) when it was launched in 2005. However, that has opened the floodgates to many more since, with today's hypercars including the LaFerrari, McLaren P1, Porsche 918, Koenigsegg One:1 and Aston Martin One-77 all commanding a seven-figure asking price.

Of course, there's a school of thought that this prominent rise in multi-million-dollar motors is simply down to the principles of supply and demand: the number of billionaires walking the planet has doubled since the 2008 financial crisis, and so luxury manufacturers may well take this into account when finalising the price points of their motoring exotica. While there may be an element of truth here, there's no getting away from the fact that as these contemporary supercars continue to try and bend the laws of physics in order to offer ever more breath-taking performance, the cost of parts, technology and even tooling required to produce the car from its outset has increased. The levy for this is passed onto the customer in order to protect a vehicle manufacturer's profits.

For example, lightweight titanium exhausts are often found at the rear of supercars, but titanium itself is an expensive material due to its durability at high temperatures and feather-light nature in comparison to more conventional materials such as steel. Similarly, carbon ceramic brakes take 20 days to produce but have a proven ability to improve braking performance (and not warp!) under extreme heat, which makes them essential for stopping a supercar capable of accelerating to great speeds. Though they perform better than steel items, the process of making ceramic brakes is a complicated one, inflating their cost significantly.

The premiums for these contemporary road rockets may be extremely high, then, but for your money you're guaranteed an exquisite supercar that boasts nothing but the zenith in craftsmanship, exclusivity and, of course, blistering performance. This has proved an attractive and ultimately popular venture for millionaires obsessed with the latest tech – and there's perhaps no better example than that of the luxury carmaker Rolls-Royce, whose sales have quadrupled since 2009.

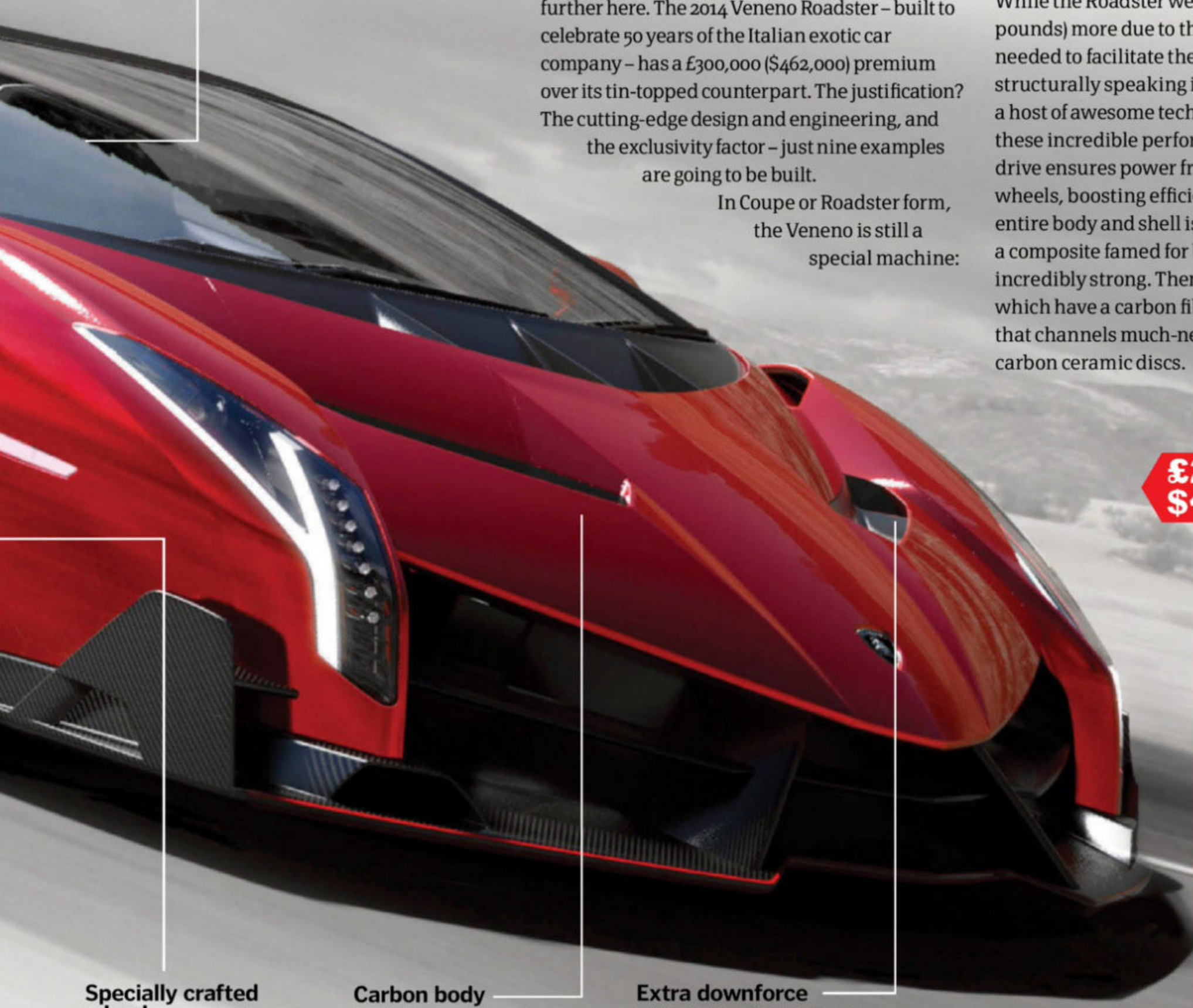
-MILLION MOTORS

LAMBORGHINI VENENO ROADSTER

It may not have a roof, yet the Veneno Roadster is still £300k more than its Coupe brethren

It's well known in motoring circles that German giant Porsche has mastered the art of charging customers more for less thanks to their veritable RS models, yet Lamborghini have gone one further here. The 2014 Veneno Roadster – built to celebrate 50 years of the Italian exotic car company – has a £300,000 ($462,000) premium over its tin-topped counterpart. The justification? The cutting-edge design and engineering, and the exclusivity factor – just nine examples are going to be built.

In Coupe or Roadster form, the Veneno is still a special machine: both iterations accelerate to 100 kilometres (62 miles) per hour in a mind-boggling three seconds before blasting on to a staggering top speed of 355 kilometres (221 miles) per hour. While the Roadster weighs 40 kilograms (88 pounds) more due to the chassis strengthening needed to facilitate the absence of a roof (which structurally speaking is an integral part of a car), a host of awesome tech is utilised to maintain these incredible performance figures. All-wheel-drive ensures power from the engine goes to all wheels, boosting efficiency, while nearly the entire body and shell is made from carbon fibre, a composite famed for being lightweight and incredibly strong. Then there are the wheels, which have a carbon fibre ring around the edge that channels much-needed cool air to the carbon ceramic discs.



Lightweight seats
The seats are made from Lamborghini's patented Forged Composite technology, which uses a resin to bind bundles of carbon fibre together.

Specially crafted wheels
Spokes on the wheels are specially designed to draw in air, cooling the brakes.

Carbon body
The entire body of the Veneno is made from the lightweight material carbon fibre, reducing overall mass.

Extra downforce
Vents in the bonnet enable air to flow up from under the car, aiding downforce by sucking the car to the floor.

£2.9 MILLION
$4.5 MILLION

POWER: 750bhp

TORQUE: 690Nm

0-100km/h: 2.9s

TOP SPEED: 355km/h

NUMBERS MADE: Nine

SPECIAL BECAUSE: Street-legal race car built to celebrate 50 years of Lamborghini.

© Lamborghini

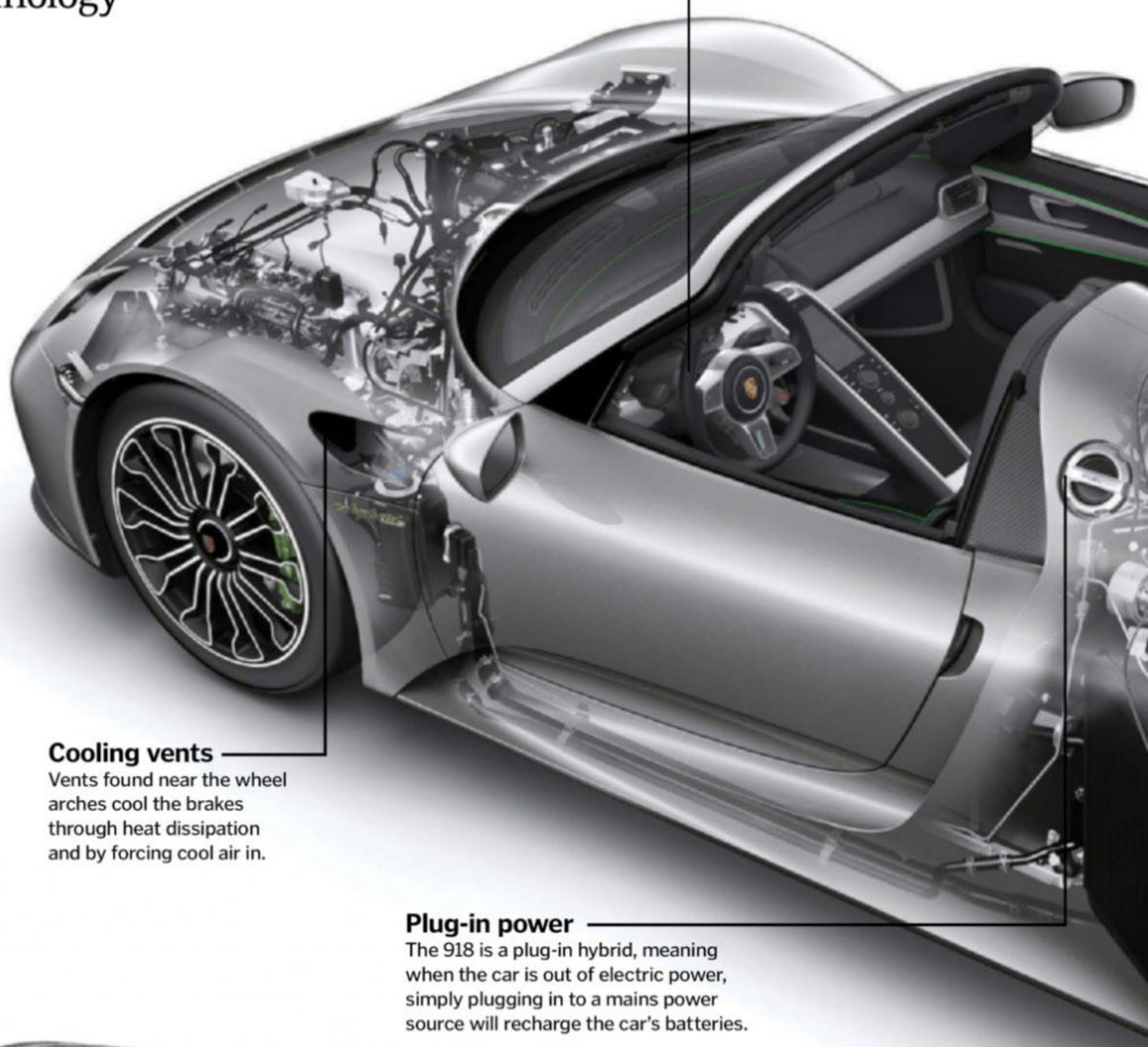
PORSCHE 918 SPYDER

Porsche's supercar of a generation melds insatiable performance with hybrid technology

The genius behind Porsche's latest hypercar lies not only in the fact that it can use its 4.6-litre V8 engine to race around the Nürburgring in just six minutes and 57 seconds (the fastest ever time for a road-legal race car). When the race track is long disposed of, the 918 can then utilise full electric mode and cruise into the heart of London and fall comfortably under the city's strict emissions regulations.

Indeed, Porsche's hypercar is a hybrid, meaning it is not only one of the fastest cars on the planet, but it is also one of the cleanest. The initial £550,000 ($845,000) fee may well make this car seem like great value compared to the Lamborghini Roadster, but optional extras on the 918 ensure the price soon rises: just take in the 'liquid metal' paint shade for some £41,000 ($63,000) – which is made up of nine super-thin layers to provide ultimate protection from stone chips without being detrimental to weight – while a clever front axle lift system helps raise the low-slung car in the event of a speed bump, all for the princely sum of £6,800 ($10,500).

Many parts of the Porsche 918 are handmade. Just one person assembles the entire V8 engine over hundreds of hours, and even the stitching around one sun visor takes a Porsche production line worker 45 minutes to do by hand, such is the high craftsmanship of Zuffenhausen's marquee supercar.



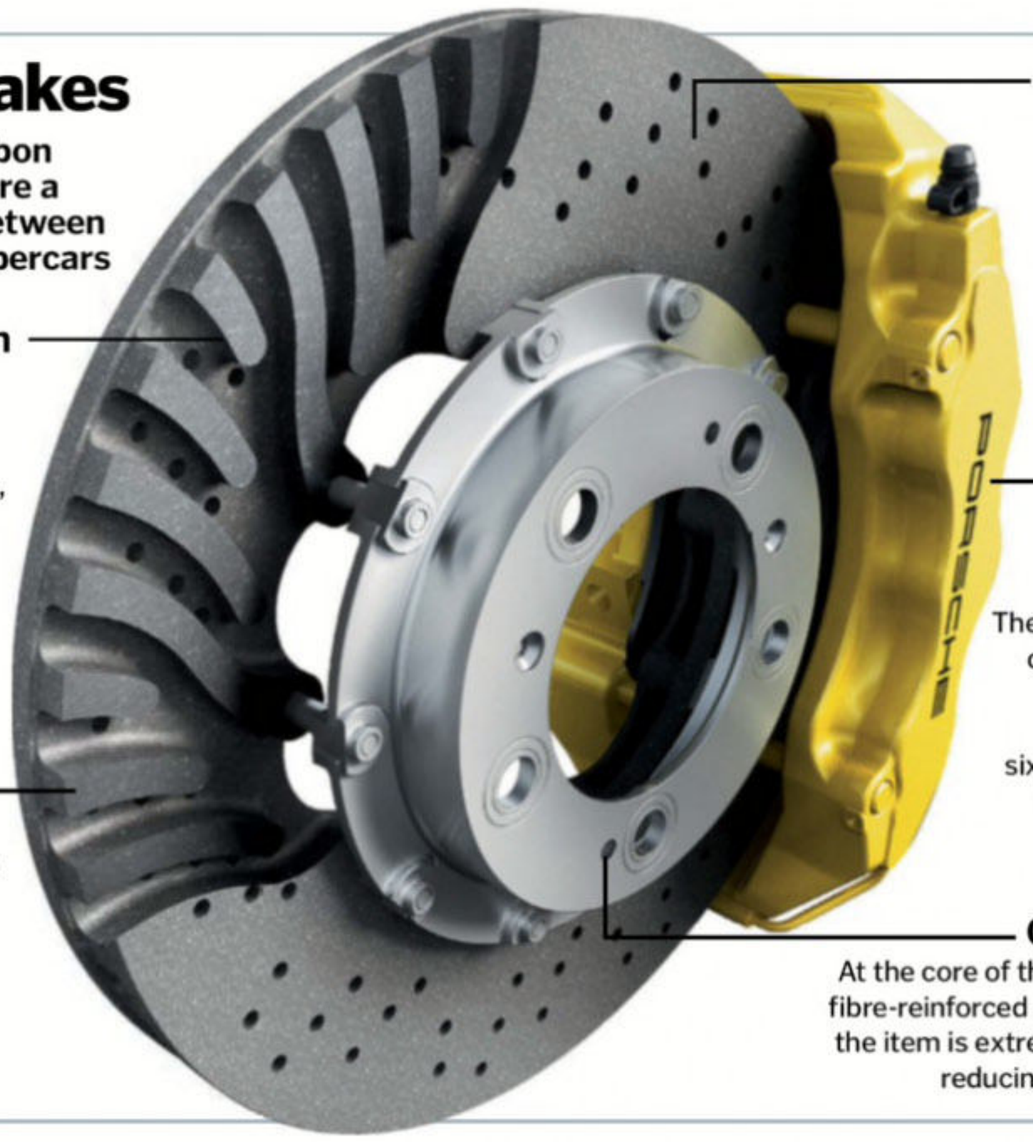
Mode selection
Switching between full race mode for the track or full hybrid mode for the city is easy; the driver merely flicks a toggle mounted on the steering wheel.

Cooling vents
Vents found near the wheel arches cool the brakes through heat dissipation and by forcing cool air in.

Plug-in power
The 918 is a plug-in hybrid, meaning when the car is out of electric power, simply plugging in to a mains power source will recharge the car's batteries.

Super brakes

Find out why carbon ceramic brakes are a common sight between the wheels of supercars



Heat dissipation
Various grooves and holes are drilled in to the discs to dissipate heat under heavy use, increasing efficiency.

No brake fade
Carbon ceramic brakes don't produce dust under heavy use, meaning cars with ceramic brakes will have cleaner wheels than those with steel.

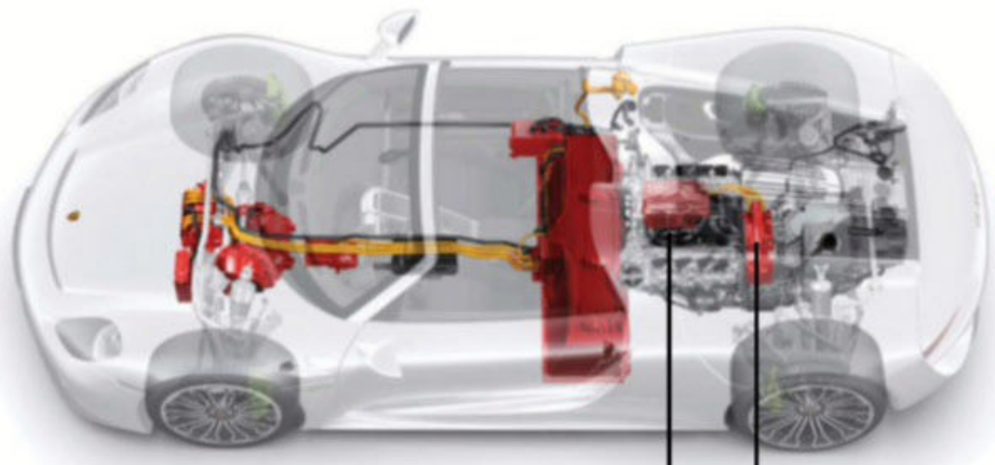
Friction coat
The discs are covered in an extra ceramic friction layer, useful when the callipers clamp hard on to the rotating disc.

Big callipers
The braking potential of ceramic discs is huge, so bigger callipers (usually six-piston) are fitted to help clamp the brake pad hard against the disc.

Ceramic core
At the core of the disc is a carbon fibre-reinforced ceramic, ensuring the item is extremely lightweight, reducing unsprung mass.

Rear steering
Like on more sporty 911s, the rear wheels of the 918 Spyder steer with the front, aiding high-speed stability on turn-in to a corner.

Want to switch between race mode and hybrid mode? Just flick a toggle on the steering wheel



Top-mounted exhaust
For the same reasons as the engine placement, the exhausts are mounted on top of the car, rather than underneath like on conventional cars.

Internal combustion engine
This is cleverly placed above the electric batteries, ensuring the heat given off rises immediately up and out the car.

Electric motor
These heavy items are mounted at the bottom of the car, lowering its centre of gravity and improving handling.

Adjustable rear wing
The 918's rear wing adjusts automatically in height and angle of attack according to the speed of the car.

Porsche 918 VS McLaren P1

WEIGHT

PORSCHE 918: 1,675kg (3,692lb)

MCLAREN P1: 1,395kg (3,075lb)

TOP SPEED

PORSCHE 918: 344km/h (214mph)

MCLAREN P1: 350km/h (217mph)

ACCELERATION (0-100km/h)

PORSCHE 918: 2.5s

MCLAREN P1: 2.8s

POWER (OF WHICH ELECTRIC)

PORSCHE 918: 887bhp (285bhp)

MCLAREN P1: 903bhp (176bhp)

POWER TO WEIGHT

PORSCHE 918: 4.16lbs/hp

MCLAREN P1: 4.3lbs/hp

DRAG COEFFICIENT (Cd)

PORSCHE 918: 0.36

MCLAREN P1: 0.34

LENGTH

PORSCHE 918: 4,646mm / 182.9in

MCLAREN P1: 4,588mm / 181in

WIDTH

PORSCHE 918: 1,941 mm / 76.4in

MCLAREN P1: 2,134mm / 84in

HEIGHT

PORSCHE 918: 1,167mm / 46in

MCLAREN P1: 1,188mm / 47in

£0.7 MILLION
$1.08 MILLION

POWER: 887bhp

TORQUE: 540Nm

0-100km/h: 2.5s

TOP SPEED: 344km/h

NUMBERS MADE: 918

SPECIAL BECAUSE: One of the fastest cars in the world – and capable of producing zero emissions!

SPYDER EXTRAS

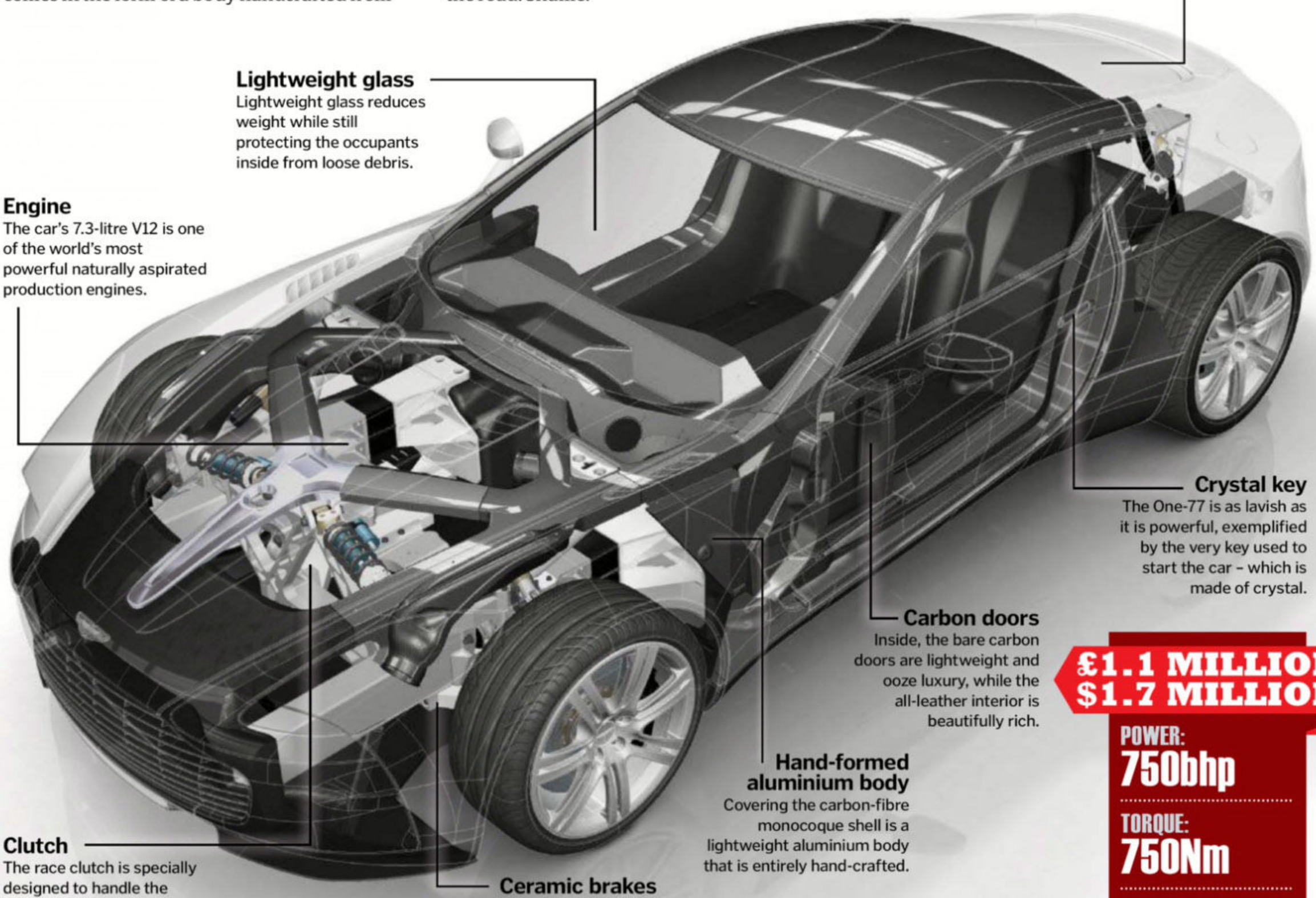
1	'Liquid metal' special edition paint	$63,000
2	Front axle lift system	$10,500
3	'Weissach Pack' weight reduction package	$84,000
4	Electric comfort heating	$6,000
5	Seat trim, authentic leather	$26,000
6	Painted platinum wheels	$5,800
TOTAL		$195,300

ASTON MARTIN ONE-77

Britain's only million-pound supercar has performance, craftsmanship and rarity in abundance

Self-billed as 'the ultimate Aston Martin', performance is assured from the monstrous V12 engine, which produces a hefty 750bhp and propels the car well past 320 kilometres (200 miles) per hour mark. Superior craftsmanship comes in the form of a body handcrafted from lightweight aluminium – a practice unheard of on modern times of mass production.

And what of its rarity? Predictably just 77 examples of the One-77 are to be produced, meaning it's unlikely that you'll ever see one on the road. Shame.



Vehicle dynamics
The One-77 is shorter than the Aston Martin DB9, lower than the Vantage and the engine is mounted low too, ensuring an exquisite driving dynamic for the One-77.

Lightweight glass
Lightweight glass reduces weight while still protecting the occupants inside from loose debris.

Engine
The car's 7.3-litre V12 is one of the world's most powerful naturally aspirated production engines.

Crystal key
The One-77 is as lavish as it is powerful, exemplified by the very key used to start the car – which is made of crystal.

Carbon doors
Inside, the bare carbon doors are lightweight and ooze luxury, while the all-leather interior is beautifully rich.

Hand-formed aluminium body
Covering the carbon-fibre monocoque shell is a lightweight aluminium body that is entirely hand-crafted.

Clutch
The race clutch is specially designed to handle the sheer power generated from the engine, ensuring smooth gear changes even at high speed.

Ceramic brakes
Like its peers, ceramics are deployed on the Aston Martin as they won't warp under the extreme heat garnered during harsh braking of the 354km/h (220mph) car.

£1.1 MILLION
$1.7 MILLION

POWER: 750bhp

TORQUE: 750Nm

0-100km/h: 3.7s

TOP SPEED: 354km/h

NUMBERS MADE: 77

SPECIAL BECAUSE: One of the most powerful naturally aspirated engines in the world is mated to the most exclusive-ever Aston Martin.

Five of the most expensive cars from the movies

Aston Martin DB5
£2.9 million/$4.4 million
Goldfinger

Batmobile
£3 million/ $4.62 million
Batman (TV series)

1965 Shelby Cobra Daytona Coupe
£5 million/$7.7 million
Red Line 7000

1961 Ferrari 250 GT
£7.1 million/$10.9 million
Ferris Bueller's Day Off

1968 Ford Gulf GT40
£7.2 million/$11 million
Le Mans

KOENIGSEGG ONE:1

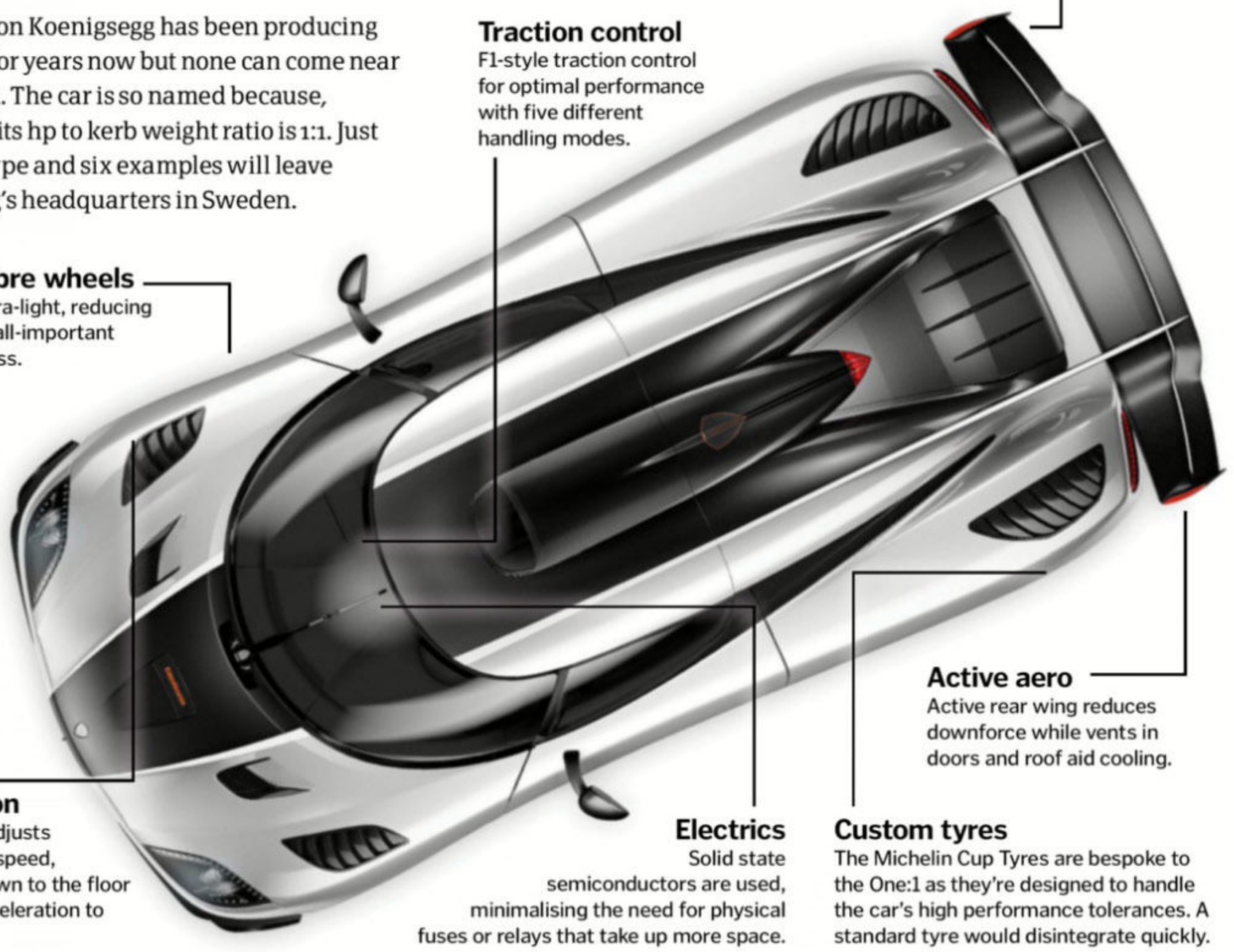
Dubbed as the world's first 'megacar', it's the first production car with one megawatt of power

Christian Von Koenigsegg has been producing crazy cars for years now but none can come near to the One:1. The car is so named because, incredibly, its hp to kerb weight ratio is 1:1. Just one prototype and six examples will leave Koenigsegg's headquarters in Sweden.

Carbon fibre wheels
These are ultra-light, reducing the vehicle's all-important unsprung mass.

Traction control
F1-style traction control for optimal performance with five different handling modes.

Underside aero
Under the chassis is perfectly flat, with venturi tunnels at the front and rear of the vehicle, producing a large 'ground effect'.



Active suspension
Ride height adjusts according to speed, hunkering down to the floor under big acceleration to reduce drag.

Electrics
Solid state semiconductors are used, minimalising the need for physical fuses or relays that take up more space.

Active aero
Active rear wing reduces downforce while vents in doors and roof aid cooling.

Custom tyres
The Michelin Cup Tyres are bespoke to the One:1 as they're designed to handle the car's high performance tolerances. A standard tyre would disintegrate quickly.

£1.8 MILLION
$2.85 MILLION

POWER: 1,341bhp

TORQUE: 1,371Nm

0-100km/h: 2.8s

TOP SPEED: 439km/h

NUMBERS MADE: Seven

SPECIAL BECAUSE: Boasting an unrivalled power-to-weight ratio of 1:1.

LaFERRARI

Ferrari's first hypercar is also its first to utilise hybrid power

Ferrari needs no introduction as one of the most prestigious manufacturers of exotic cars in the world, but the LaFerrari is extra special because, for the first time, Ferrari has turned to electric assistance to help boost power of its famous internal combustion engine. Unlike the P1 or 918, which can run on electric mode only, the LaFerrari makes use of its Formula One-oriented KERS system (which recovers a vehicle's moving energy under braking) at the rear axle to add to the power of its 6.3-litre V12 engine to produce a jaw-dropping 950bhp. This is part of an array of technology the hypercar hijacks from Ferrari's successful Formula One racing team.

£1.15 MILLION
$1.76 MILLION

POWER: 950bhp

TORQUE: 900Nm

0-100km/h: 2.4s

TOP SPEED: >350km/h

NUMBERS MADE: 499

SPECIAL BECAUSE: Quite simply the most technologically advanced road-going Ferrari ever made.

How to fly a helicopter

Find out what it takes to fly these amazing aircraft

Piloting this incredible piece of engineering is no mean feat. Immense mental and physical co-ordination is required; the ability to use each hand and foot independently to operate the flight controls is a prerequisite for any prospective pilot. This means training to become a pilot takes a significant amount of time and money. Typically more than 1,000 registered flying hours and numerous written exams are needed if you want to fly commercially.

Advancements in helicopter technology

A number of recent advancements have improved on the existing helicopter design. One of these is the no-tail rotor, or NOTAR. This functions to solve two commonly encountered problems; namely the noise made by the tail rotor and the ease with which it can be damaged.

It works by blowing spent air from the helicopter's main rotor down the tail boom. Slots located on the tail boom allow the air to escape, producing a sideways force that works to oppose the torque generated by the main rotor. By varying the amount of air expelled, this can also aid directional control.

A second engine is also being fitted to some helicopters, which functions as a fail-safe if the main engine were to stop working. Either engine is capable of keeping the aircraft airborne, enabling the pilot to land safely in the event of an engine malfunction.

This Belgian police helicopter features the innovative no-tail rotor (NOTAR) system

Inside the cockpit

Learn how these controls enable a pilot to manoeuvre a helicopter

1 Centre console

The radio and transponder tend to be located on the centre console. A variety of other instrumentation will also be present, including master switches for the engine, and multiple temperature gauges.

2 Instrument panel

Similar to an aeroplane, there are a number of instruments that need constant monitoring while airborne, including speed indicators, as well as the altitude (height) and attitude (forward speed) values.

3 Anti-torque pedals

Located at the front of the cockpit are two pedals, which control the tail rotor. Operating the pedals causes a lateral change in direction, and is used to combat the torque created by the main rotors during takeoff, which causes the helicopter to turn.

4 Cyclic-pitch lever

Sitting between the pilot's legs, the cyclic-pitch lever works to tilt the aircraft forwards, backwards or side-to-side. It tilts the rotor disc in the desired direction of flight, changing the angle of the rotor blades to alter the helicopter's direction.

5 Collective-pitch lever

This works to move the aircraft up and down, and is used during the helicopter's takeoff. When engaged, a collective change is imparted on the pitch of all the aircraft's rotor blades, by changing the angle of the swashplate (inset image). The throttle is also located here, which controls the engine's power.

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Awesome power

See inside the lead submarine of the Ohio class

Engine room
The engine room houses the gearing, generator and engine turbine. The nuclear reactor provides enough power to reach submerged speeds of over 20 knots (37 kilometres/23 miles per hour).

Crew quarters
With nine crewmembers bunked per room, the crew quarters are cramped. Each sailor gets their own bunk pan to store personal belongings.

Nuclear reactor
The S8G nuclear reactor weighs 2,750 tons, and is 17 metres (55 feet) long. It provides a whopping 44,742 kilowatts (60,000 shp) of power.

Command control centre
This is the submarine's brain, where all its controls are located. The periscope is also accessed here.

Inside a nuclear submarine

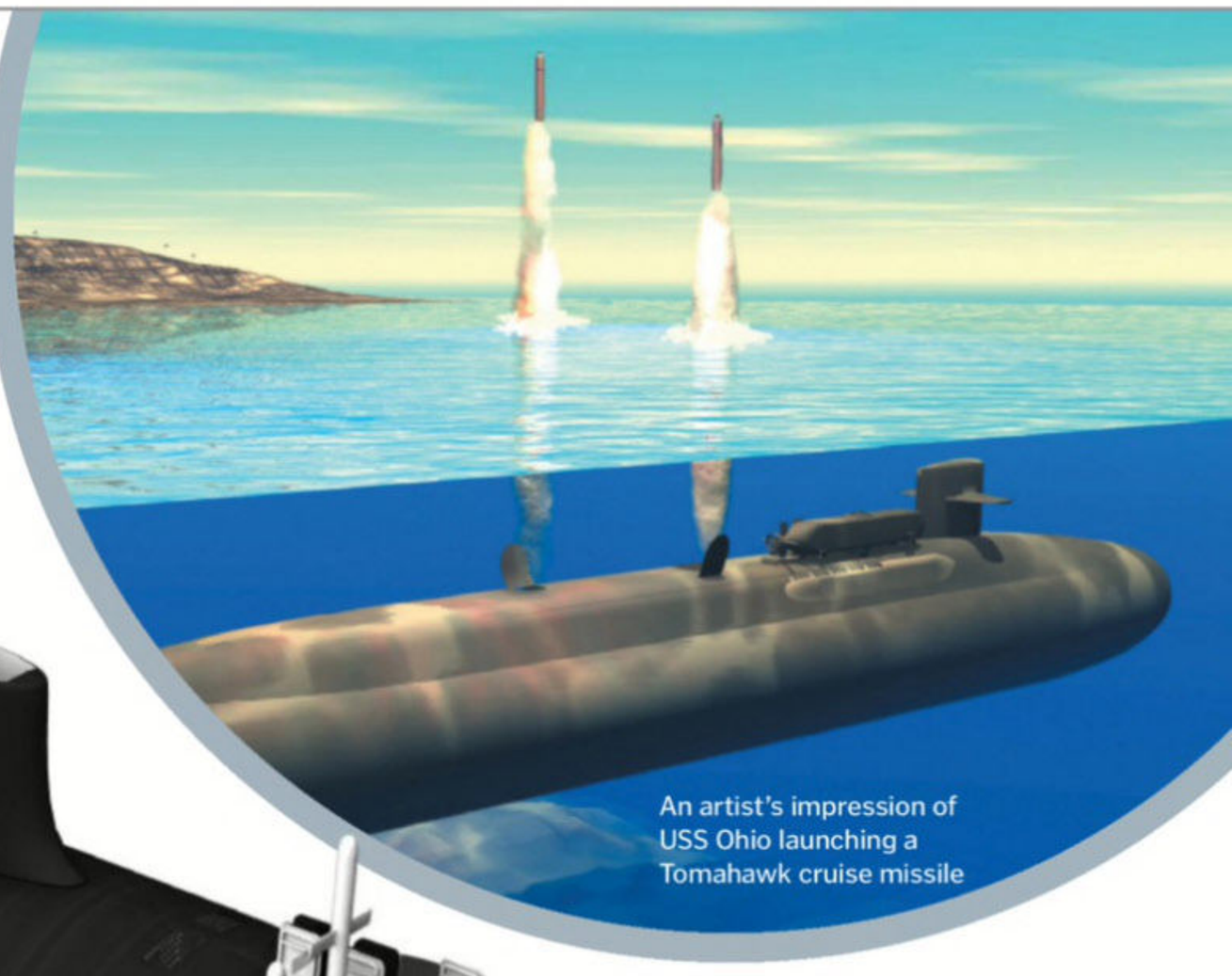
Learn the secrets behind one of the United States' most powerful weapons

USS Ohio patrols the world's oceans in stealth and silence, virtually undetectable. It's longer than the Washington Monument is high, measuring an impressive 170 metres (558 feet). USS Ohio is the lead submarine of the Ohio class, the United States Army's largest nuclear-powered submarines. This class is made up of 18 submarines, all of which were originally equipped with a full nuclear armament of ballistic missiles. Between 2002 and 2008, the US Navy modified the four oldest Ohio-class submarines (which included USS Ohio) into guided-missile submarines (SSGN), which carry non-nuclear missiles. The remaining 14 carry roughly 50 per cent of the United States' active thermonuclear warheads. One of the silos that held a nuclear missile before USS Ohio was modified is now a hatch to allow Navy Seals to exit the submarine for covert operations.

USS Ohio has been designed to be highly self-sufficient, capable of producing its own power, drinking water and oxygen. It produces breatheable air via a clever process that uses electricity to separate oxygen from the hydrogen in seawater. This allows USS Ohio to remain submerged for up to 90 days; the only limitation being food supplies. A large crew is required to operate USS Ohio and will typically include 15 officers in addition to 140 other sailors. All of the crew are exceptional sailors, and volunteer to go aboard the submarine.

Plans have been announced to replace the Ohio-class submarines in the near future. The US Navy is currently in the early stages of the Ohio Replacement Program, with construction of the new submarines scheduled to begin by 2021. Financial limitations are becoming an issue, as each replacement submarine is predicted to cost more than £3.2 billion ($4.9 billion). Until this new breed of submarines materialise, USS Ohio and the rest of the Ohio class will remain a formidable resource for the United States' military.

"It's longer than the Washington Monument is high, measuring an impressive 170 metres"



An artist's impression of USS Ohio launching a Tomahawk cruise missile

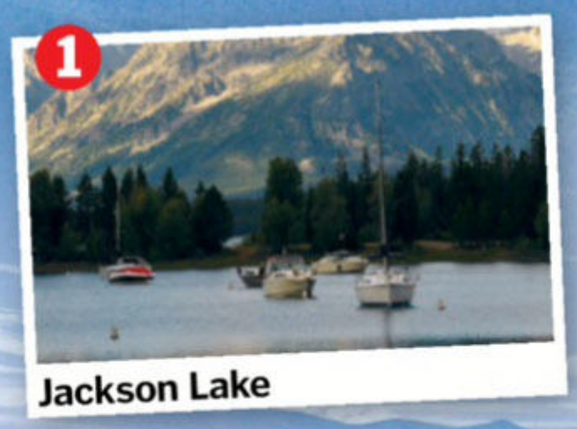
Missile tubes
USS Ohio has 22 missile tubes, which each house seven Tomahawk cruise missiles, meaning it can carry a total of 154 of these long-range weapons.

Torpedoes
The submarine is armed with MK-48 torpedoes. These torpedoes have a 295-kilogram (650-pound) warhead, with a range of 50 kilometres (31 miles).

Sonar dome
The bow of the submarine houses the sonar dome which transmits and receives acoustic signals.

Image by Alex Pang

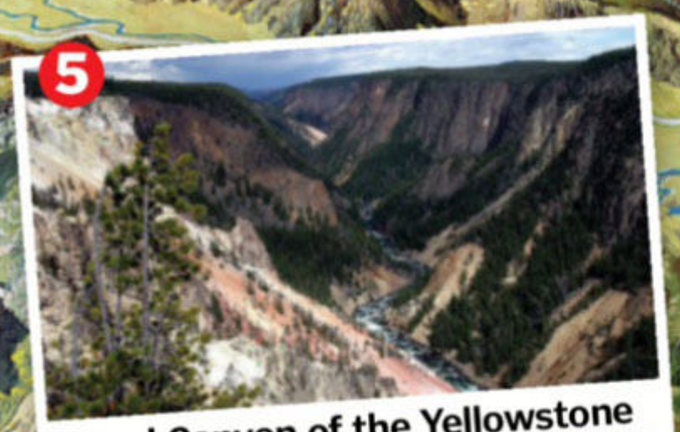
Wonders of YELLOWSTONE


1
Jackson Lake


2
Grand Teton


3
Heart Lake


4
Yellowstone Lake


5
Grand Canyon of the Yellowstone


6
Lewis Lake

PARK

Wild beasts, 30-metre high geysers and a supervolcano that could destroy America

Welcome to Yellowstone Park – America's, and the world's, very first national park. Its vast swath of 9,000 square kilometres (3,500 square miles) of protected land, which spans the borders of Wyoming, Montana and Idaho, could house all five boroughs of New York City ten times over, and attracts over 3 million visitors each year.

Its world-renowned scenery includes soaring peaks, plunging canyons, lush forests, rushing rivers, brilliant lakes, rolling meadows, thundering waterfalls, shimmering hot springs and gushing geysers. Amid all this visual poetry lives a rich assortment of wildlife, including wolves, bears, bison and elk.

Yellowstone National Park was established by US Congress in 1872, soon after the first Europeans arrived in the American West, but archaeological records show that people have been in Yellowstone for over 11,000 years. Many tribes have lived on and passed through the land now occupied by the park, including the famous Native American Sheepeaters.

The park lies at the heart of the Greater Yellowstone Ecosystem, which at over 80,000 square kilometres (30,000 square miles) is one of the largest nearly intact temperate-zone ecosystems on Earth. It preserves a staggering variety of terrestrial, aquatic and microbial life, making it a truly invaluable resource for scientists who are conducting various studies, ranging from landscape-level changes right down to some of the tiniest microscopic organisms imaginable.

Yellowstone was set aside as the world's first national park primarily because of its extraordinary geology and hydrothermal wonders. The park contains around half of all the hydrothermal features on Earth – over 10,000 of them – including hot springs, mud pots, fumaroles and the world's greatest concentration of geysers. The most famous of these, Old Faithful, is a perennial crowd pleaser that reliably erupts almost once every hour.

Yellowstone's hydrothermal features are fuelled by volcanic activity deep within the Earth. Just a few miles underneath the park, partially molten rock churns and seethes. The area has seen three gargantuan volcanic eruptions and at least 30 smaller ones over the last two million years, and the park and its immediate surroundings typically experience between 1,000 and 3,000 earthquakes each year, with several large enough to be felt by visitors.

Visitors, wildlife, and the park's pristine landscapes are managed and protected by a team of rangers – 780 work during the peak summer season and a core 355 are permanent year-round employees. As you might expect, competition to become a park ranger at Yellowstone is fierce. Can you imagine a better "office" to go to each day?

Animals of Yellowstone

As well as breathtaking scenery, Yellowstone is home to a staggering diversity of wildlife. The region sustains one of the largest communities of free roaming large animals seen anywhere on Earth, and contains the most powerful mega fauna in the contiguous US. Following the re-introduction of grey wolves in 1995, today's Yellowstone boasts almost the full complement of animal species that inhabited the park when it was first explored over a century ago.

As well as wolves, some of the major attractions for park visitors are the two types of bears – grizzlies and black bears – bison, wild horses and America's national bird, the bald eagle. Among the animal species are 67 mammals, nearly 300 birds, 16 fish, four amphibians and six reptiles, which can be found within the park's boundaries. The variety and abundance of wildlife is due, in part, to the collection of specialist habitats it encompasses. The animals are also protected by law; only park rangers may fire guns, although visitors can obtain fishing permits.

But that isn't to say that life in Yellowstone is a walk in the park for its inhabitants. They must endure cold harsh winters, with temperatures at or below freezing from November through to March and snowfall heavy enough to cause the main roads to be closed for months on end. Each species has its own way of coping – from the moose's specially hinged joints, which they can swing over the snow rather than having to plough through it, to the bison's tendency to graze and find warmth near hydrothermal areas.

The entire Yellowstone ecosystem exists as a delicate balance between predators, prey, and their habitat – itself governed by climate fluctuations, forest fires, invasive species and volcanic activity. The way the park is managed today reflects shifting attitudes and new understanding about this balance. For example, wolves, once considered too great a threat to other species, are now recognised as linchpins in the health and stability of the overall ecosystem. Forest fires were once viewed purely in terms of the death and destruction they cause, but today controlled burns are recognised as a critical step in the natural cycle of regeneration and renewal.

Yellowstone is the only place in the contiguous US where bison have roamed continuously since prehistoric times

DID YOU KNOW? *During the 1988 "summer of fire" 36 per cent of the park was affected by wildfires*

Moose
Bulls shed their heavy antlers at the start of winter to conserve energy.

American white pelican
Forms spring nesting colonies on Yellowstone Lake, but overwinters in the coastal waters of Mexico, California and the south-eastern US.

Lesser Scaup

Green-winged Teal

Trumpeter swans (pair)

Uinta ground squirrel

Black bear

Yellowstone bison (and calf)
Uses its giant head as a snowplough to clear deep snow and find food.

Yellow-bellied marmot
Hibernates for up to eight months of the year, surviving entirely on stored fat.

Pika
Spends summer gathering vegetation for winter food, which it builds into vigorously defended "haystacks".

Pronghorn

How wolves balance the Yellowstone ecosystem

An icon of the wilderness, the grey wolf once thrived in Yellowstone before it became systematically shot, trapped and poisoned until it was finally eradicated from the park in 1926. But without the wolves the entire ecosystem went into free-fall; the deer population exploded and grazed almost all the vegetation bare, causing a cascade of knock-on effects.

In 1995, 14 wolves were reintroduced to the park. Where the deer avoided the wolves, woody vegetation flourished and beavers – whose dens are important to otters, fish, reptiles and amphibians – were bolstered. Wolves kept the coyote population in check, which boosted numbers of small mammals. Bears thrived on wolves' discarded carcasses and the new proliferation of berries. Even rivers were affected with their banks strengthened by improved plant growth, erosion slowed and they meandered less.

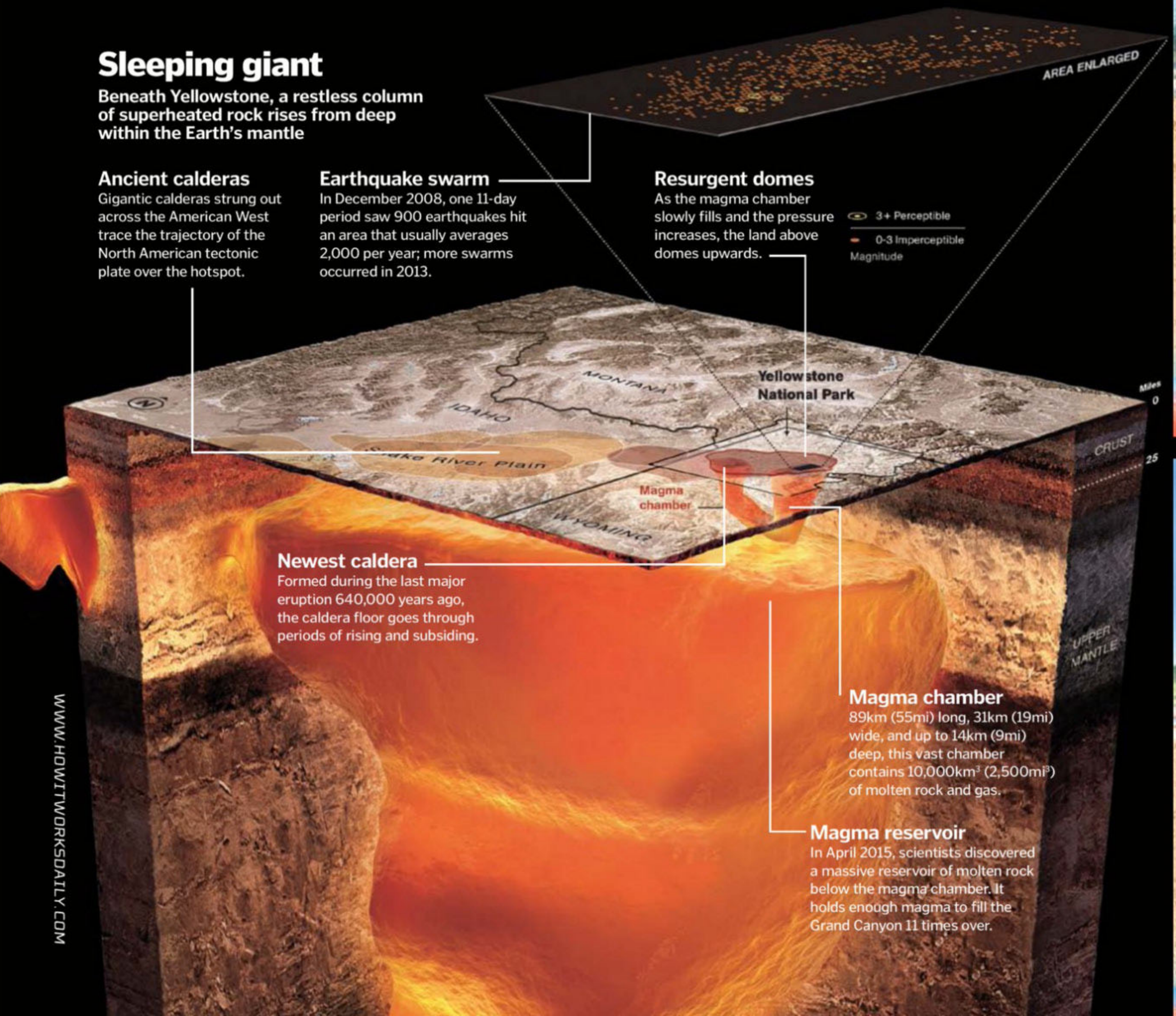
What lies beneath...?

Yellowstone's natural serenity belies its violent volcanic underbelly. In fact, one third of the park's area lies within the gigantic caldera of a colossal supervolcano. These types of volcanoes are defined by their ability to eject more than 1,000 cubic kilometres (240 cubic miles) of material – making them at least a thousand times larger than the 1980 Mount Saint Helens eruption, the deadliest and most destructive volcanic eruption ever recorded in US history.

Yellowstone's super volcano is powered by an immense geological hotspot, which fuels a growing magma chamber directly underneath the park. Three massive eruptions have occurred within Yellowstone – 2.1 million, 1.3 million, and 640,000 years ago respectively – a regular pattern that leads many experts to believe a globally catastrophic eruption is long overdue.

Sleeping giant

Beneath Yellowstone, a restless column of superheated rock rises from deep within the Earth's mantle



Ancient calderas
Gigantic calderas strung out across the American West trace the trajectory of the North American tectonic plate over the hotspot.

Earthquake swarm
In December 2008, one 11-day period saw 900 earthquakes hit an area that usually averages 2,000 per year; more swarms occurred in 2013.

Resurgent domes
As the magma chamber slowly fills and the pressure increases, the land above domes upwards.

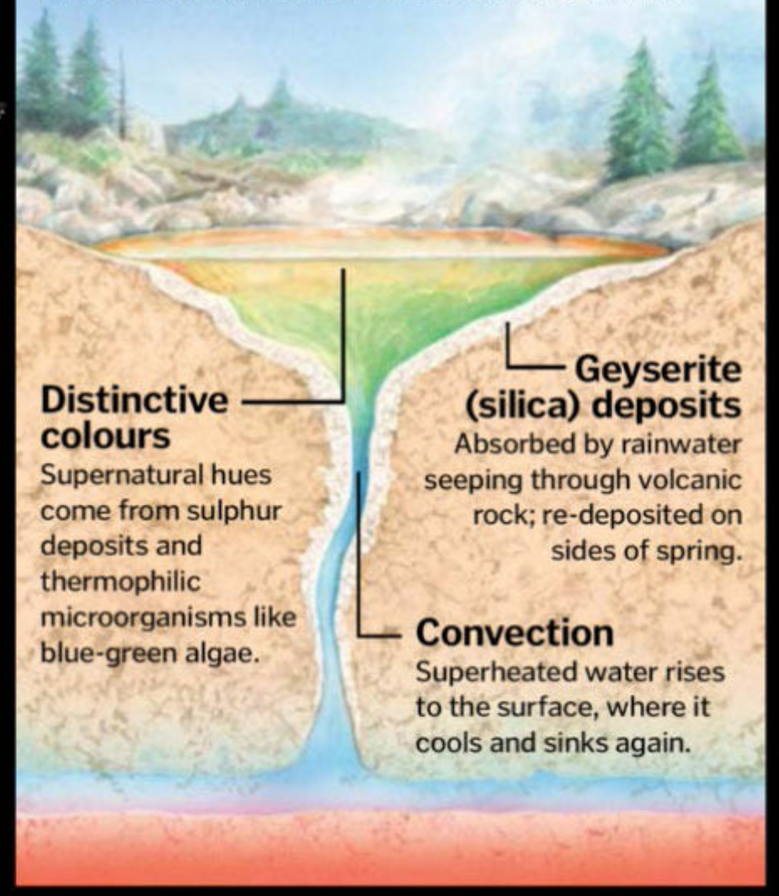
Newest caldera
Formed during the last major eruption 640,000 years ago, the caldera floor goes through periods of rising and subsiding.

Magma chamber
89km (55mi) long, 31km (19mi) wide, and up to 14km (9mi) deep, this vast chamber contains 10,000km³ (2,500mi³) of molten rock and gas.

Magma reservoir
In April 2015, scientists discovered a massive reservoir of molten rock below the magma chamber. It holds enough magma to fill the Grand Canyon 11 times over.

Guide to Yellowstone's hydrothermal features

Hot springs
The most common type of thermal feature in Yellowstone, formed when rain and snow seeps through the underlying bedrock and becomes superheated from the energy radiated by partially molten rock that lie a few miles below the surface.

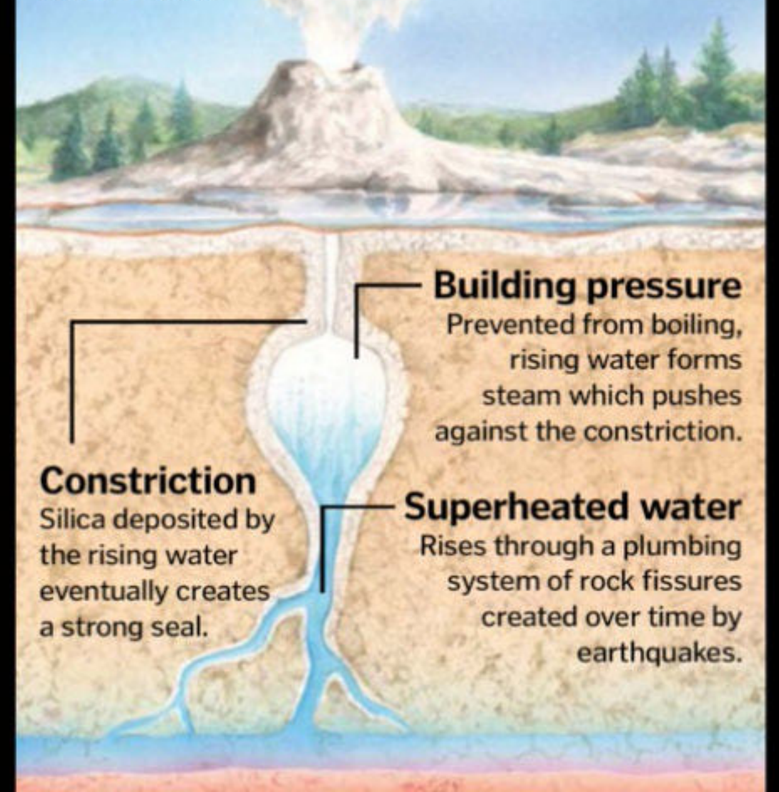


Distinctive colours
Supernatural hues come from sulphur deposits and thermophilic microorganisms like blue-green algae.

Geyserite (silica) deposits
Absorbed by rainwater seeping through volcanic rock; re-deposited on sides of spring.

Convection
Superheated water rises to the surface, where it cools and sinks again.

Geysers
A rare kind of hot spring that forms when a plumbing constriction prevents superheated water from circulating freely. Pressure builds as rising water is prevented from boiling, until eventually the geyser blows, spewing huge volumes of steam and water from its vent.



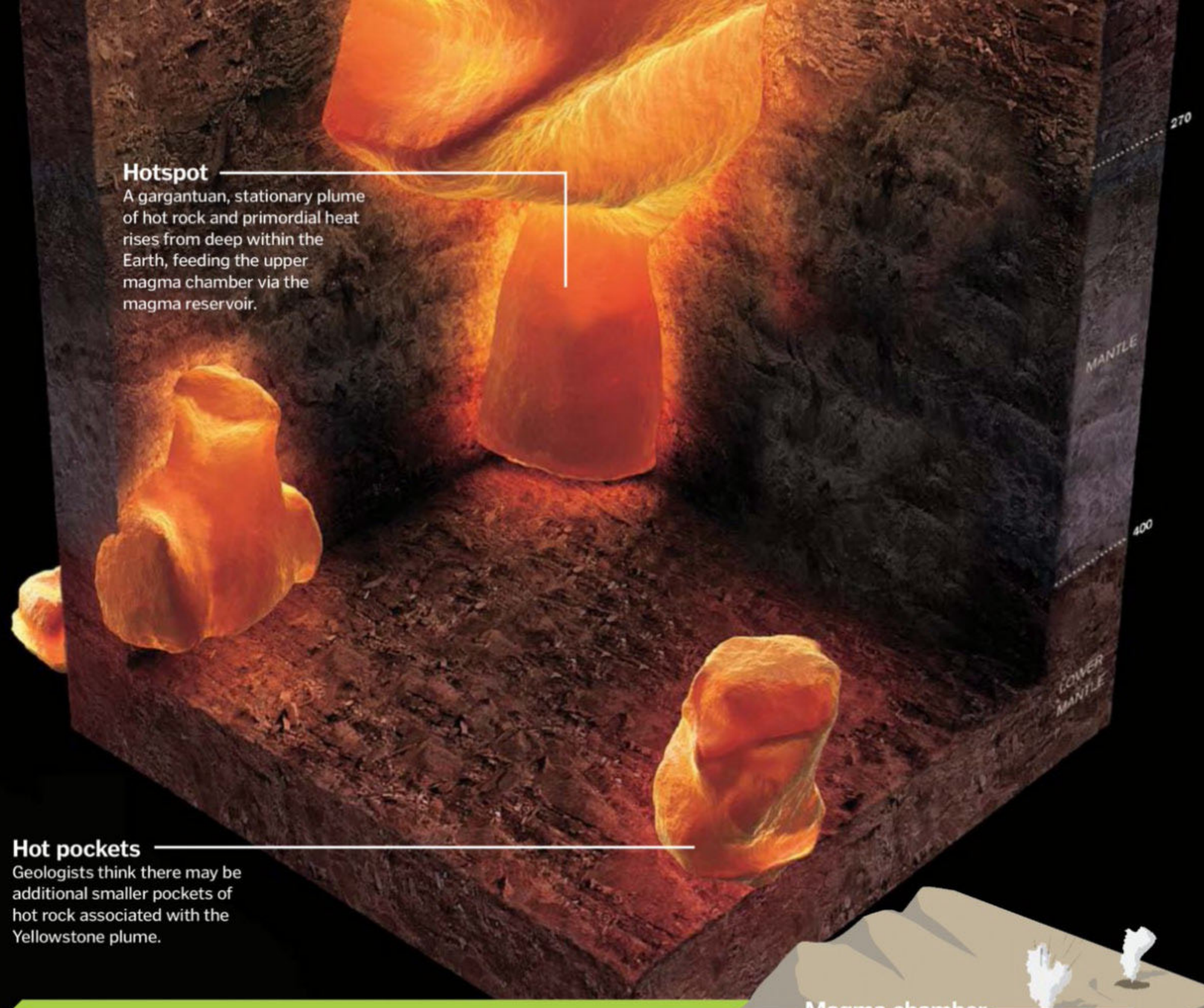
Building pressure
Prevented from boiling, rising water forms steam which pushes against the constriction.

Constriction
Silica deposited by the rising water eventually creates a strong seal.

Superheated water
Rises through a plumbing system of rock fissures created over time by earthquakes.

Hotspot
A gargantuan, stationary plume of hot rock and primordial heat rises from deep within the Earth, feeding the upper magma chamber via the magma reservoir.

Hot pockets
Geologists think there may be additional smaller pockets of hot rock associated with the Yellowstone plume.

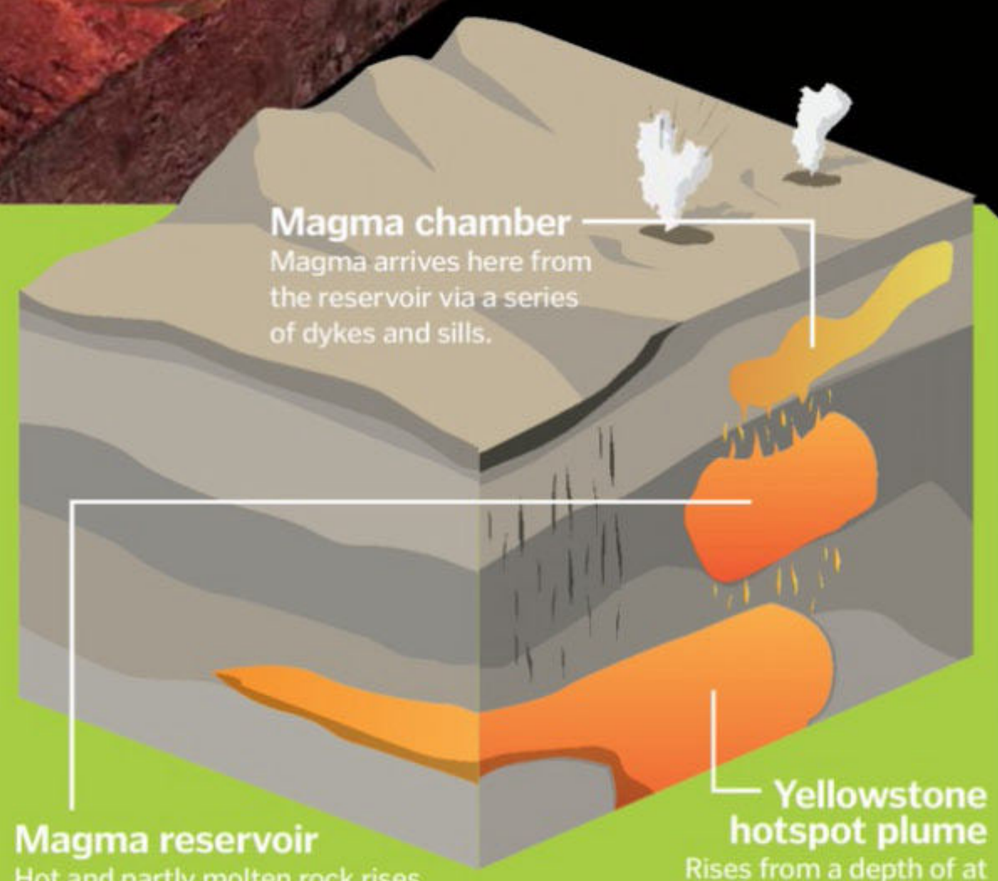


What if Yellowstone blows?

Geologists have never witnessed a supervolcanic eruption, but by looking at remnants of previous cataclysms, mapping the underground bodies of magma and using computer models, they can glean horrifying details about what might happen if Yellowstone blows.

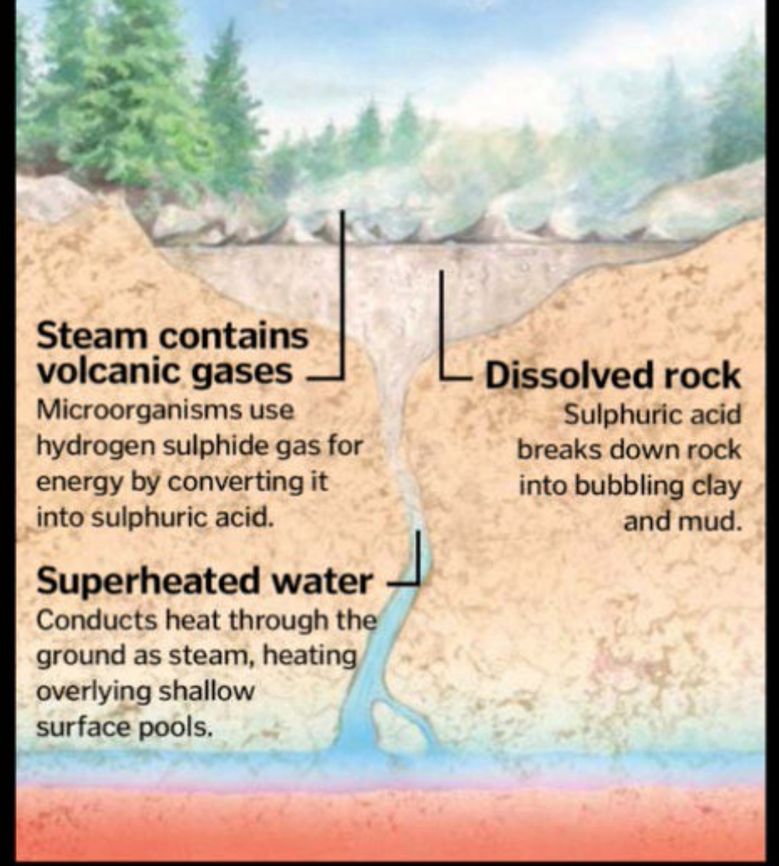
Gas-filled magma would explode from the volcano, raining rocky debris and hot, dense ash – a mix of splintered rock and glass capable of killing people and animals in a most gruesome fashion as they inhale it – across tens of thousands of square kilometres. A high-altitude umbrella cloud would spread out in all directions, blanketing the Rocky Mountains with metres of ash and sending particles across the entire country.

The cloud would temporarily shut down air travel and interfere with electronic communications across North America. Roofs would collapse under the weight of ash; roads, sewers and water supplies would become clogged and unusable, and crops would be smothered. The states of Wyoming, Montana, Idaho, Colorado and Utah would be devastated, perhaps unliveable for several years, and the entire globe would cool by a couple of degrees as gas from the cloud blocks out the Sun, causing climatic effects that could threaten many species with extinction.



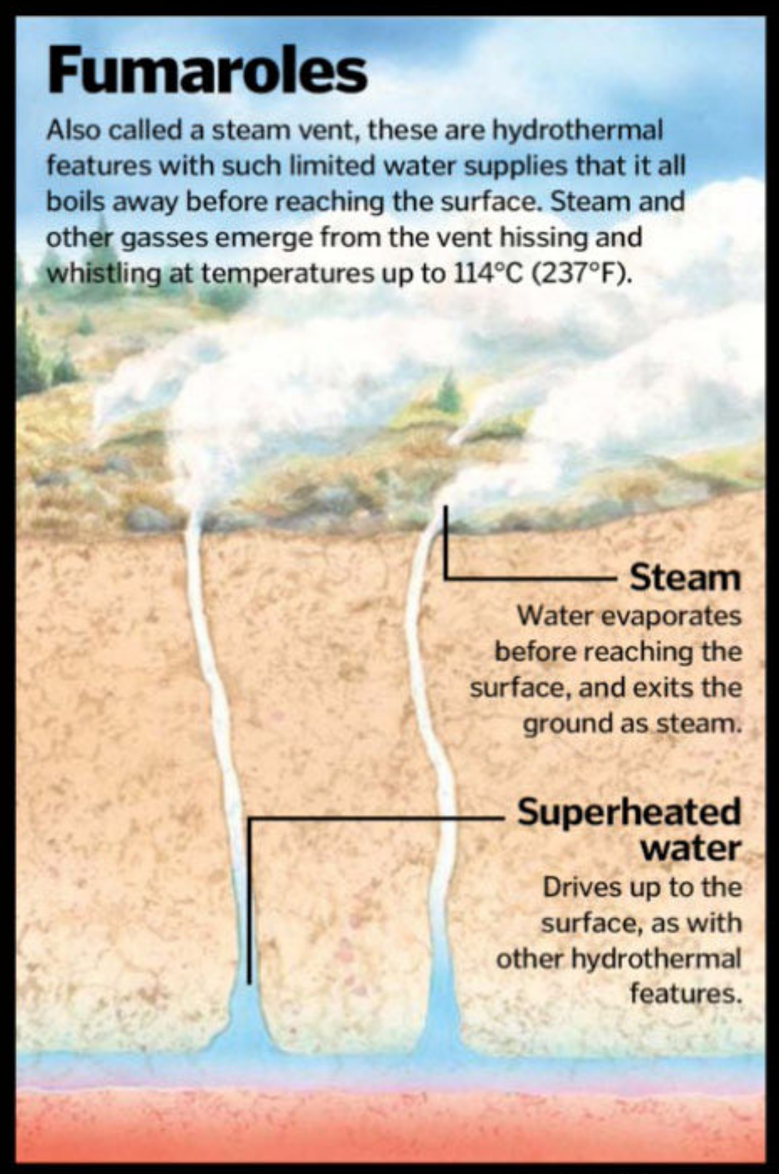
Mud pots

Steaming vents of hydrogen sulphide acidify shallow, heated pools of surface water which turns the underlying rock into bubbling blue-grey clay. Minerals in the clay interact with the acids resulting in a shimmering rainbow of coloured deposits.



Fumaroles

Also called a steam vent, these are hydrothermal features with such limited water supplies that it all boils away before reaching the surface. Steam and other gasses emerge from the vent hissing and whistling at temperatures up to 114°C (237°F).



DID YOU KNOW? Geyser water's round trip can take hundreds or even thousands of years

Image by Ed Crooks

Images by Peter Scott/Art Agency

Light pillars

The cause of false UFO reports explained

It may look like a fleet of alien spaceships has arrived to beam up humans from Earth, but this bizarre image has actually captured a rare atmospheric and optical phenomenon. The bright vertical columns in the sky are called light pillars, but they are only visible under very specific conditions. They form when light from a source low in the sky – such as the setting Sun or even streetlights – reflects off of millions of flat, hexagonal ice crystals in the air and into your eyes or camera. Therefore, the columns of light you see are not physically there, but if you stand in the right spot, with the ice crystals roughly halfway between you and the light source, then the optical illusion occurs. As well as being cold enough for the ice crystals to form, the weather must also be very calm so that the crystals can fall gently through the air while remaining in a horizontal orientation, tilting slightly from side to side. It's these tilted crystals that elongate the reflection into a column, and the higher they are in the sky, the taller the column will be.

Light pillars form due to the light of the Moon or street lights

Photo by Christoph Geisler

How do flying fish fly?

Discover the clever technique that gets these aquatic creatures airborne

Is it a bird? Is it a plane? No, it's actually a fish. Strictly speaking though, flying fish don't really fly. They use their fins to help them glide through the air, but they don't flap them like wings. The fish developed this technique to help them escape predators in the water, but they can't remain airborne for long as they need to return to the water to breathe.

Flying fish can glide for up to 45 seconds at a time

1 Speedy swimming
The fish begins by swimming really fast underwater. They can reach speeds of over 60 kilometres (37 miles) per hour.

2 Streamlined body
When swimming, the fish folds its fins against its body to make it more streamlined and gain speed.

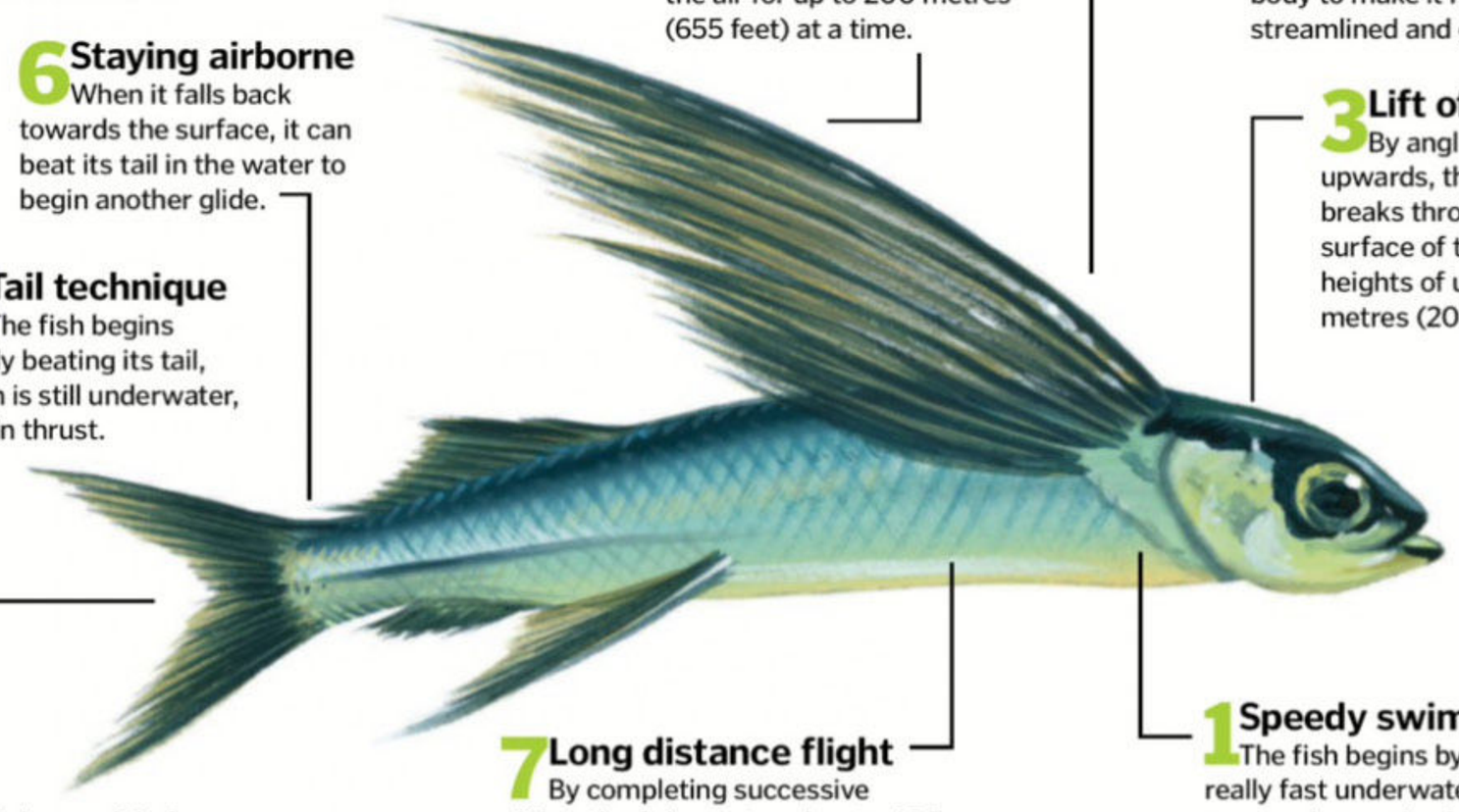
3 Lift off
By angling its body upwards, the fish breaks through the surface of the water to heights of up to six metres (20 feet).

4 Tail technique
The fish begins rapidly beating its tail, which is still underwater, to gain thrust.

5 Gliding
By spreading its fins, the fish can glide through the air for up to 200 metres (655 feet) at a time.

6 Staying airborne
When it falls back towards the surface, it can beat its tail in the water to begin another glide.

7 Long distance flight
By completing successive glides, the fish can travel up to 400 metres (1,312 feet) through the air.



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The ever-changing Plitvice Lakes

How incredible geology has formed Croatia's waterfall paradise

The spectacular Plitvice Lakes are actually part of one large river flowing between the Mala Kapela and Licka Plješivica mountains in central Croatia. The river has divided into this series of interconnected lakes and waterfalls because of a geological phenomenon known as a karst landscape, where rock, water and organisms all work together to create new features.

The Plitvice river basin is made of limestone and dolomite, and as the water passes through it dissolves these rocks and becomes saturated with calcium carbonate. This chemical compound then sticks to the mucus secreted by the microscopic bacteria and algae that grow on moss plants in the water. The plants gradually become encrusted with the calcium carbonate and it slowly builds up at a rate of about one centimetre (0.4 inches) per year to form barriers of travertine rock. Some of these barriers, which have been growing since the Upper Triassic period, are around 4,000 meters (13,123 feet) thick and act as natural dams that split the river into lakes. As more water travels down from the mountains, it flows over these barriers to create waterfalls that cascade down the river basin.

Just as quickly as the flowing water erodes the travertine, more is formed when the calcium carbonate-saturated water pools at the base of the waterfalls. This means that the Plitvice Lakes are constantly changing size and shape as old waterfalls run dry and new ones form.

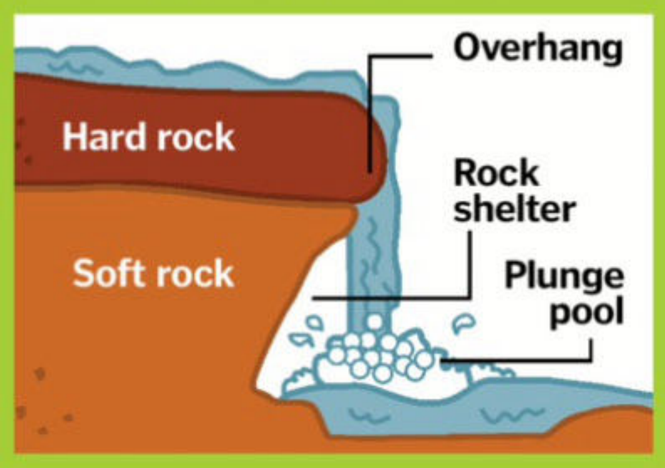
This clever geology is also responsible for giving the Plitvice Lakes their distinctive blue-green colour. When the white calcium carbonate coats the bottom of the lakes it reflects sunlight and the sky to create vivid colours that change depending on how the Sun's rays hit the water and how many organisms and minerals are present.

"The Plitvice Lakes are constantly changing size and shape"

DID YOU KNOW? *Plitvice Lakes National Park is a UNESCO World Heritage Site and is home to many endangered species*

How does a waterfall form?

Usually, waterfalls form when a river flows over areas of soft and hard rock. The flowing water erodes the soft rock more quickly than the hard rock, undercutting it to leave an overhang. This forms a basic waterfall, and as the water flows over this ledge, it often takes some rocks with it. These rocks crash into the riverbed below, so more erosion occurs to form a plunge pool. The soft rock behind the waterfall is also eroded as water splashes at the bottom, cutting into the rock to form a cave-like structure called a rock shelter. Eventually the water erodes the overhang of hard rock too, causing the waterfall to recede upstream. This process is slightly different to that which occurs at the Plitvice Lakes, as instead of carving existing rock into an overhang, the mineral-rich water there helps to create new ledges that the water can flow over.



The tallest Plitvice waterfall is over 70 metres (230 feet) high, the equivalent of almost 16 double-decker buses stacked on top of each other

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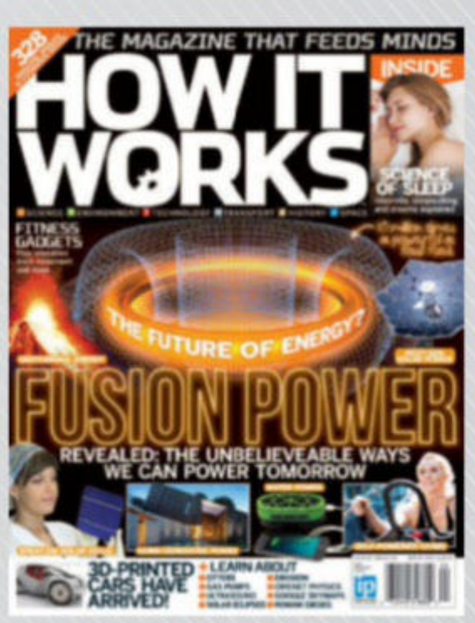

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DID YOU KNOW? *During the migration period, local golfing rules change to enable red crabs to move the ball*

'Crab crossings' are set up to reduce the number of crabs crushed by vehicles during the migration period

Learn more

To find out when this year's migration is likely to take place and plan a trip to the Island, visit **www.christmas.net.au**.

Red crabs greatly outnumber Christmas Island's human population of around 2,000 people

Red crabs regularly invade local golf courses on their way to the coast

Red crab invasion

Discover the amazing migration of 120 million crabs

Once a year on Christmas Island, Australia, an incredible phenomenon takes place. Tens of millions of red crabs descend from the rainforest, turning the island into a sea of red as they make their way to the coast to breed. The migration begins with the wet season, typically around October or November, and is linked with the phases of the Moon and therefore the tide.

It's the males that leave their forest burrows first, and once they reach the shore they have a quick dip in the sea to replenish any body moisture lost during their journey. They then start to dig burrows in the sand and, once the females arrive, they enter the burrows to begin mating. After mating, the males make their return journey leaving the females in the burrows to develop up to 100,000 eggs. About 12 to 13 days later, before dawn at high tide, the females emerge from the burrows and go to sea.

Once they reach the water they deposit their eggs, which immediately hatch into larvae. In the water, the larvae grow into prawn-like creatures called megalopae that breathe through gills. Those that manage to survive the harsh ocean currents and marine predators emerge from the sea four weeks later to shed their outer skin and become baby crabs. The infants, measuring just 5mm (0.2cm) across, begin their march inland to live on the forest floor, then after four years, they progress to join the migrating herds for breeding, and the cycle begins all over again.

Life on Titan

Is there life among the chaotic, carbon-based chemistry of this ice-cold world?

With a thick atmosphere teeming with organic compounds and stable liquids on its surface, many believe that Titan is among the most likely locations for life. We know that sunlight destroys methane so something must be replacing Titan's atmospheric content; could this be an extraterrestrial life form?

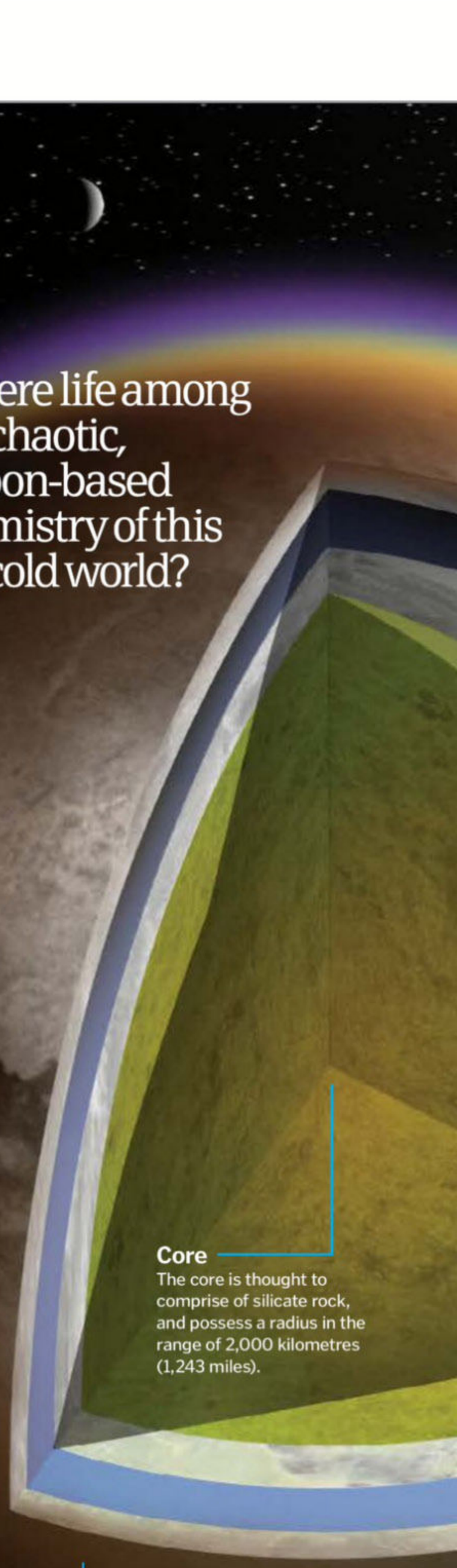
Of the 62 different moons that orbit Saturn, none possess the same potential to change the way we see our universe as Titan. Labelled by some as the most mysterious object in our Solar System, this moon is the largest orbiting Saturn and is the second largest overall; beaten only by Jupiter's moon Ganymede.

The surface of Titan shares many similarities with Earth. It has lakes, seas, rivers, shorelines and highlands. The confirmation of liquid on Titan's surface was a hugely significant finding. However, this surface liquid is not water, it is methane, one of many hydrocarbons that reside on this moon. It is also thought that a hydrological cycle is present, which revolves around methane and its conversion from liquid to gas and back again. This Earth-like climate system reinforces Titan's status as the most similar planetary body to our planet.

The majority of our knowledge of Titan can be credited to the Cassini-Huygens mission. The Cassini spacecraft was launched in 1997, tasked with the examination of Saturn and its surrounding rings and moons. Equipped with the Huygens probe, Cassini reached Saturn seven years later, and began its observations of this distant part of the Solar System. On 14 January 2005 the Huygens probe parachuted down through Titan's thick, orange haze of an atmosphere, and became the first object to land in the outer Solar System.

Many experts argue that the key to life is liquid, as we know the chemical processes required for life need a liquid medium. On Earth we know this liquid is water, but on Titan it could well be methane. NASA is planning future missions to Titan in the hope of delving deeper into the mysteries of this unusual planetary body. In the coming decades, they hope to reveal the first signs of life on Titan, using the latest investigative space technology to explore its monstrous seas and freezing landscape.

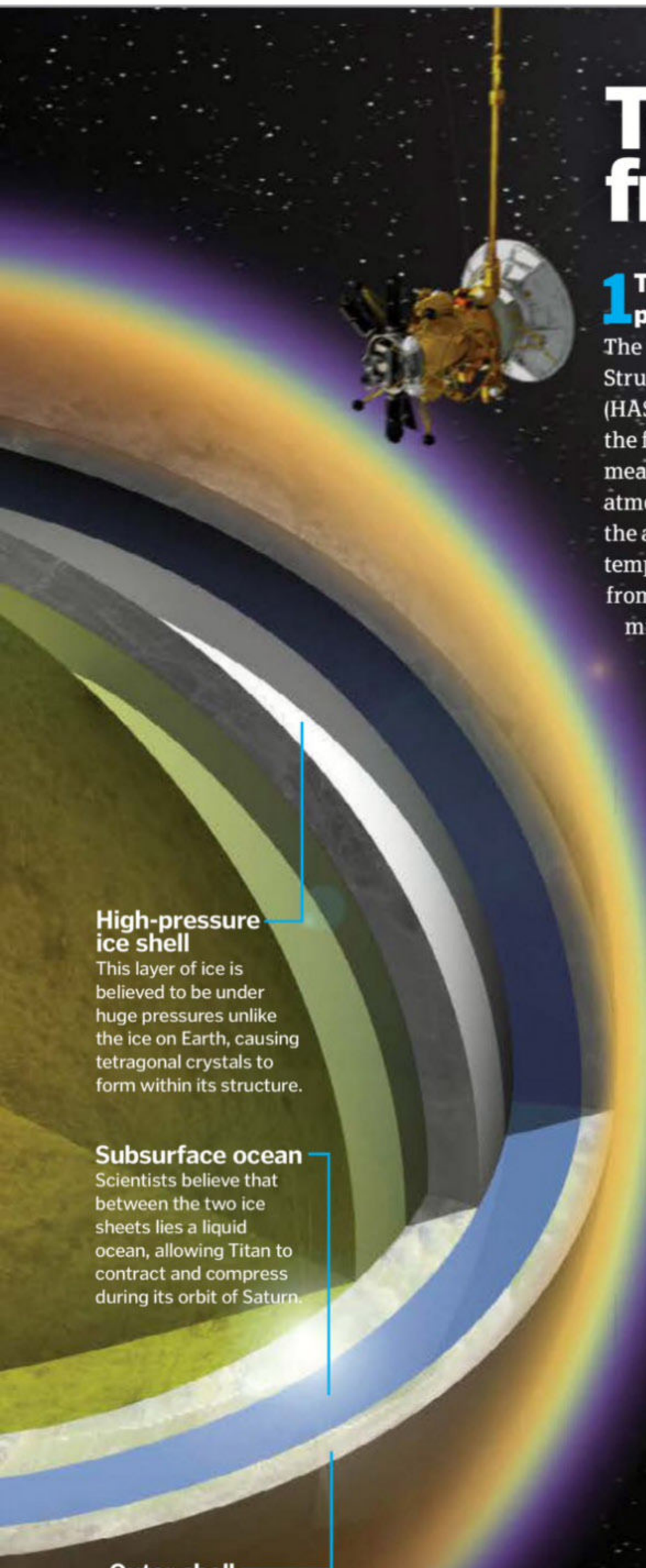
Titan's liquid abundance
Titan is the only other world in our Solar System where stable liquids can be found on its surface. Moreover, it has its own hydrological cycle, including lakes, rivers and possibly even rain.



Core
The core is thought to comprise of silicate rock, and possess a radius in the range of 2,000 kilometres (1,243 miles).

Organic-rich surface
Both the atmosphere and surface of Titan are rich with organics, including complex hydrocarbons. Methane rain may form an icy crust on the surface.

Ten things we've learned from the Huygens probe

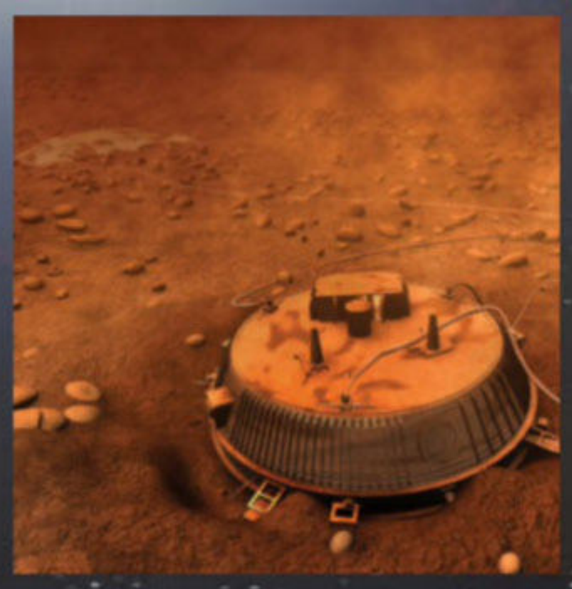


1 Titan's atmospheric profile

The Huygens Atmospheric Structure Instrument (HASI) was able to perform the first direct measurements of Titan's atmosphere. It determined the atmospheric pressure, temperature and density, from 1,400 kilometres (870 miles) above the surface.

2 Rotating winds

Throughout Huygens' descent to Titan's surface, wind measurements were taken. At altitudes greater than 45 kilometres (28 miles), wind speeds were far greater than the moon's rotational speed, confirming the predicted superrotation of its atmosphere.



3 Mysterious methane

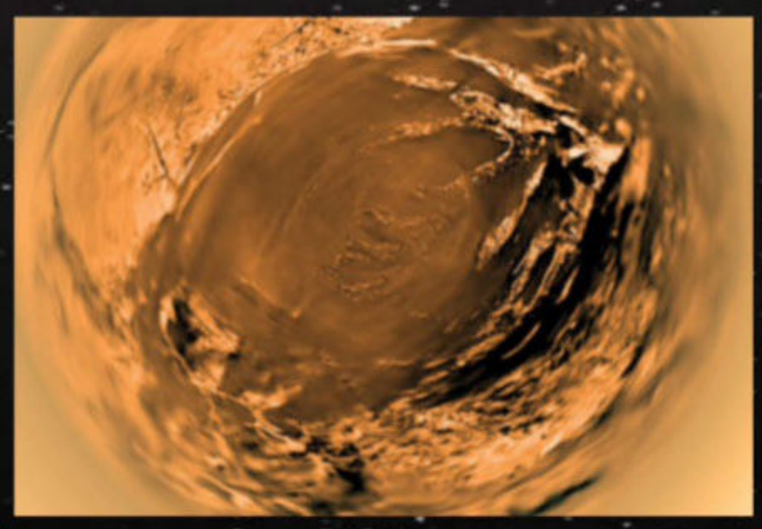
Although Huygens was unable to unearth the source of methane on Titan or how it is replenished, it did confirm its presence both in the atmosphere and on the surface.

4 Origins of nitrogen atmosphere

Prior to Huygens, the Voyager mission data had implied that Titan's atmosphere contained nitrogen. Huygens was able to prove this, its data suggesting that it originated from ammonia or another nitrogen-containing compound.

5 Cryovolcanism

Huygens detected argon-40, which originates from a potassium isotope found in rocks. This is a strong indication of geological activity, potentially in the form of cryovolcanoes, which erupt volatile liquids rather than molten lava.



6 Titan's haze

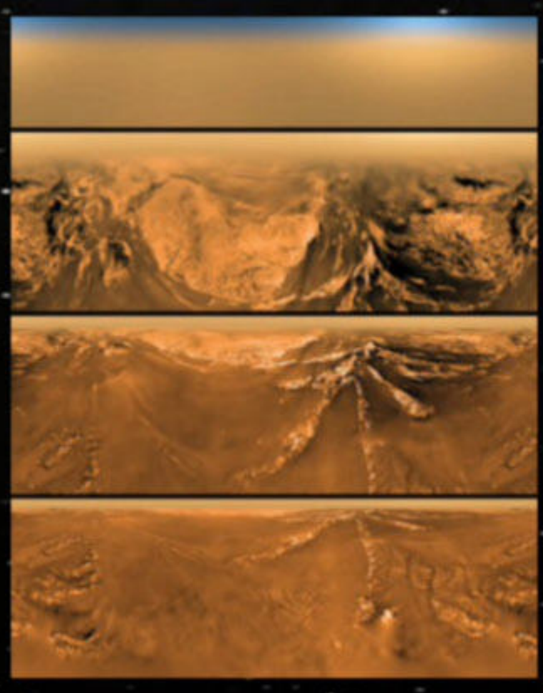
Huygens showed that Titan's blanket of orange haze extended all the way down to the moon's surface. It also revealed the size and optical properties of Titan's haze particles.

7 Tiny aerosols

The Huygens probe performed detailed analysis of the aerosols in Titan's atmosphere, by heating them in an oven and identifying the gases released. Both ammonia and hydrogen cyanide were detected.

8 Dry river beds

A definite highlight of Huygens' work was the capture of several hundred images of Titan's surface. Dry riverbeds and lakes were pictured for the first time, alongside highland terrain and rounded cobbles.



9 Evidence of subsurface ocean

Although the probe didn't detect any lightning, an unusual source of electrical excitation within the moon's atmosphere was identified. Scientists believe this could be attributed to a conductive, subsurface ocean, deep beneath Titan's surface.

10 Distinctive dunes

Initially, scientists struggled to locate Huygens' landing site using images from the Cassini orbiter. This was due to the presence of vast dunes, thought to be composed of sand-sized hydrocarbons.

Future space tech on Titan

The autonomous technology that NASA hopes will solve many of Titan's mysteries

Drones and motherships

The Titan Aerial Daughtercraft has been put forward by the NASA Innovative Advanced Concepts (NIAC) programme with the aim of sending a small quadcopter drone to Titan, alongside a mothership. The drone would operate above the moon's surface, landing on the ground to take samples when required. When the drone's charge runs out, it would be able to return to the mothership, where it could recharge and then continue its mission.

Unlike the Mars rovers, the drone would be designed to work autonomously. It would be left to gather research for days at a time, before returning its data to Earth via the mothership. As it stands there is no set date for such a mission to Titan, however the interest that has been sparked by the Huygens probe will no doubt encourage this mission to materialise.

View of Saturn
From the side of Titan's surface that constantly faces the ringed planet, Saturn would just be visible through the thick hazy atmosphere.

Drone charging
When low on power, the drone could automatically return to the mothership to recharge, before starting another set of samples.

Drone flight
The drone is likely to weigh less than ten kilograms (22 pounds), and will be capable of taking high-resolution pictures while it collects samples.

Surface samples
One of the drone's primary objectives would be to collect surface samples, including soil and liquid.

Scientific instruments
The submarine will be equipped with an array of scientific instruments, allowing it to examine the chemical composition of Titan's seas, and to check for signs of life.

Intelligent design
Although the final design is still to be confirmed, the submarine is likely to have a light, enabling it to see clearly underwater.

Submarine mission

The Kraken Mare is the largest known sea on Titan. Scientists are interested in exploring this giant liquid mass, which is over 1,000 kilometres (621 miles) wide, and is thought to be roughly 300 metres (984 feet) deep. The NIAC has proposed an autonomous submarine, which could search the hydrocarbon seas while a drone scans the land above. The primary aim would be to study the sea's liquid composition closely, to find out exactly what it is made of. Furthermore, the submarine would search for signs of plant or microbial life, which could be lurking deep beneath the liquid's surface. This data would then be transmitted back to Earth via a mothership once the submarine returned to the surface.

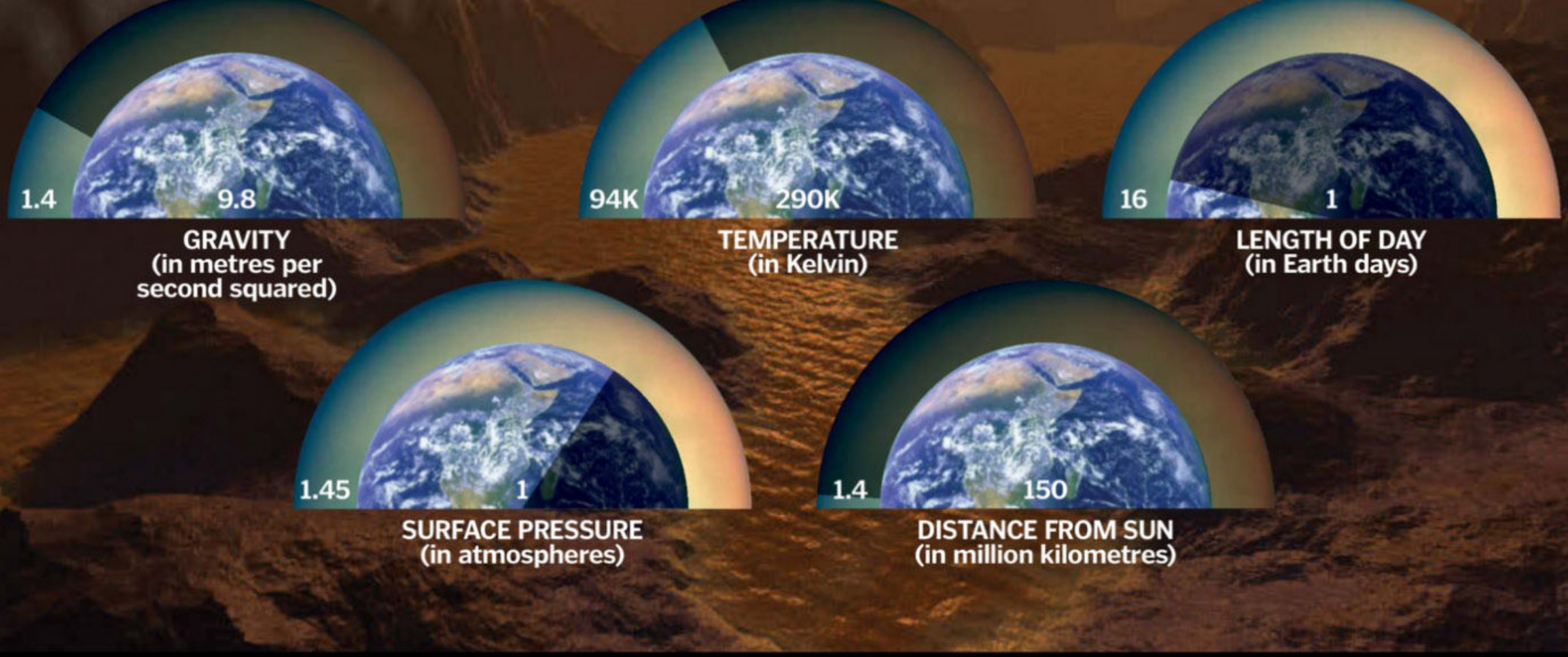
Could we survive on Titan?

It's fair to say that Titan is one of the most Earth-like worlds we've visited, which raises the question of whether humans could colonise it. There are a number of possible benefits, none of which are greater than the potential use of Titan's natural resources. In fact, data from Cassini suggests that Titan has more liquid hydrocarbons than all the known natural gas and oil resources on Earth.

If there is a large volume of water trapped beneath this moon's surface, it could be used to generate breathable oxygen. Furthermore, by combining Titan's water and methane, it would be possible to create rocket fuel that could be used as a power supply. While nitrogen, methane and ammonia – all thought to be present on Saturn's largest moon – could be used to produce fertiliser to help grow food.

There are a number of issues that humans on Titan would face. The extreme temperatures mean that we would need large heat generators and insulation units just to stop ourselves from freezing. The effects of living in lower gravity might also cause long-term issues; studies are currently being conducted to examine this.

In spite of that, Titan may still be a better choice than Mars. It already has a dense, protective atmosphere; Mars will require extensive terraforming before an atmosphere of any kind can be created. Mars also lacks natural resources, and unlike Titan, does not benefit from an induced magnetosphere to deflect the harmful solar winds.



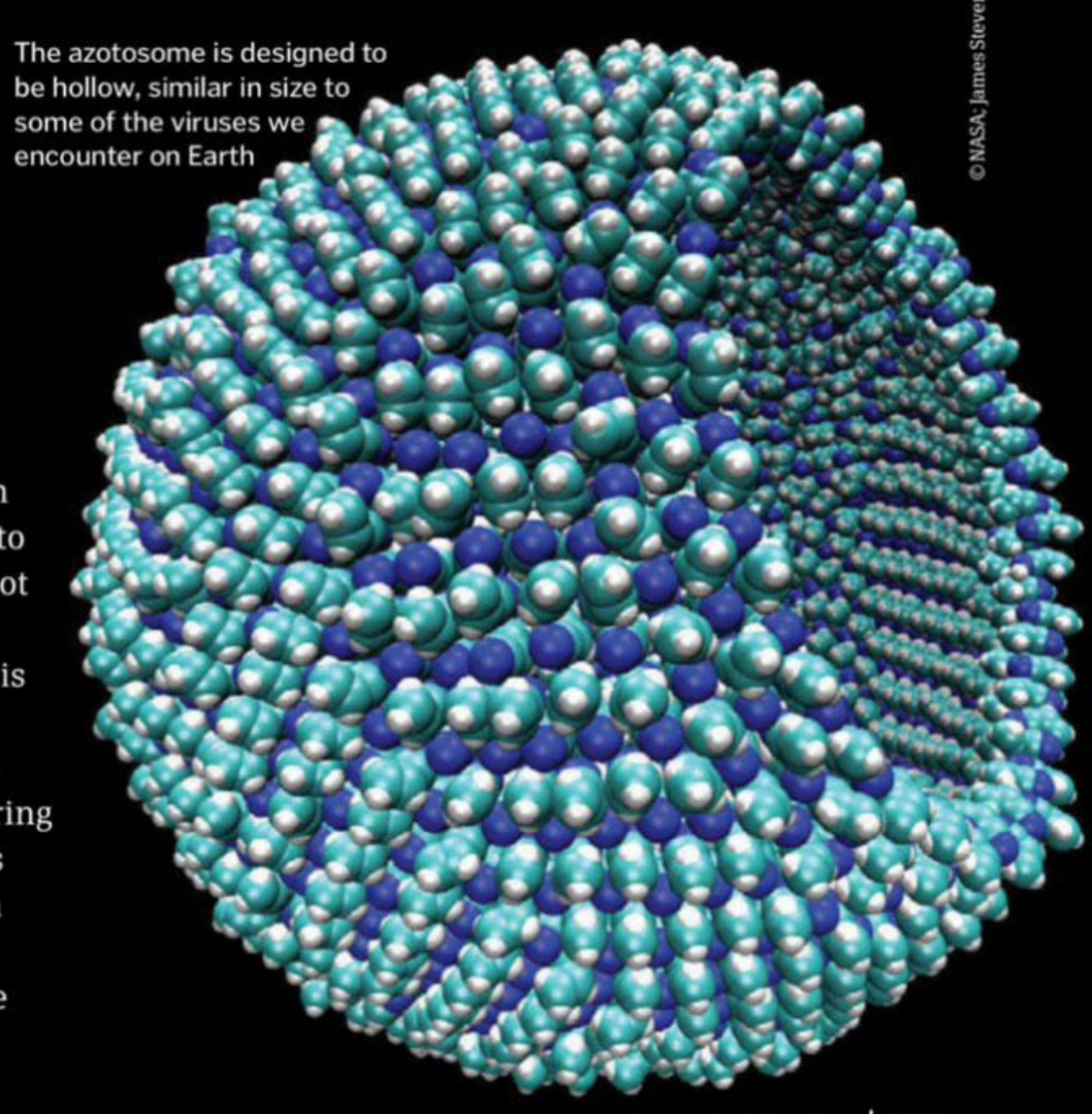
Engineering a template for life

See the cellular design that could thrive in the harsh conditions on Titan

When astronomers search for extraterrestrial life in the Solar System, they focus on one area in particular. This area is known as the circumstellar habitable zone, which is the small region around the Sun in which liquid water can exist.

But what if life could exist without water? This thought inspired scientists to create a cellular structure based on methane, which has a much lower freezing point than water and is abundant on Titan. They named their conceptual structure the 'azotosome'.

Cells on Earth all comprise of a phospholipid bilayer membrane, which houses the insides of every cell known to us. This water-based structure would not be able to function on Titan, due to the extreme temperatures. The azotosome is made up of carbon, nitrogen and hydrogen, all of which exist in the seas of Titan. The next step for these pioneering chemical engineers and astronomers is to show how these cells would function within Titan's methane environment, in particular how they might reproduce and metabolise.


The azotosome is designed to be hollow, similar in size to some of the viruses we encounter on Earth

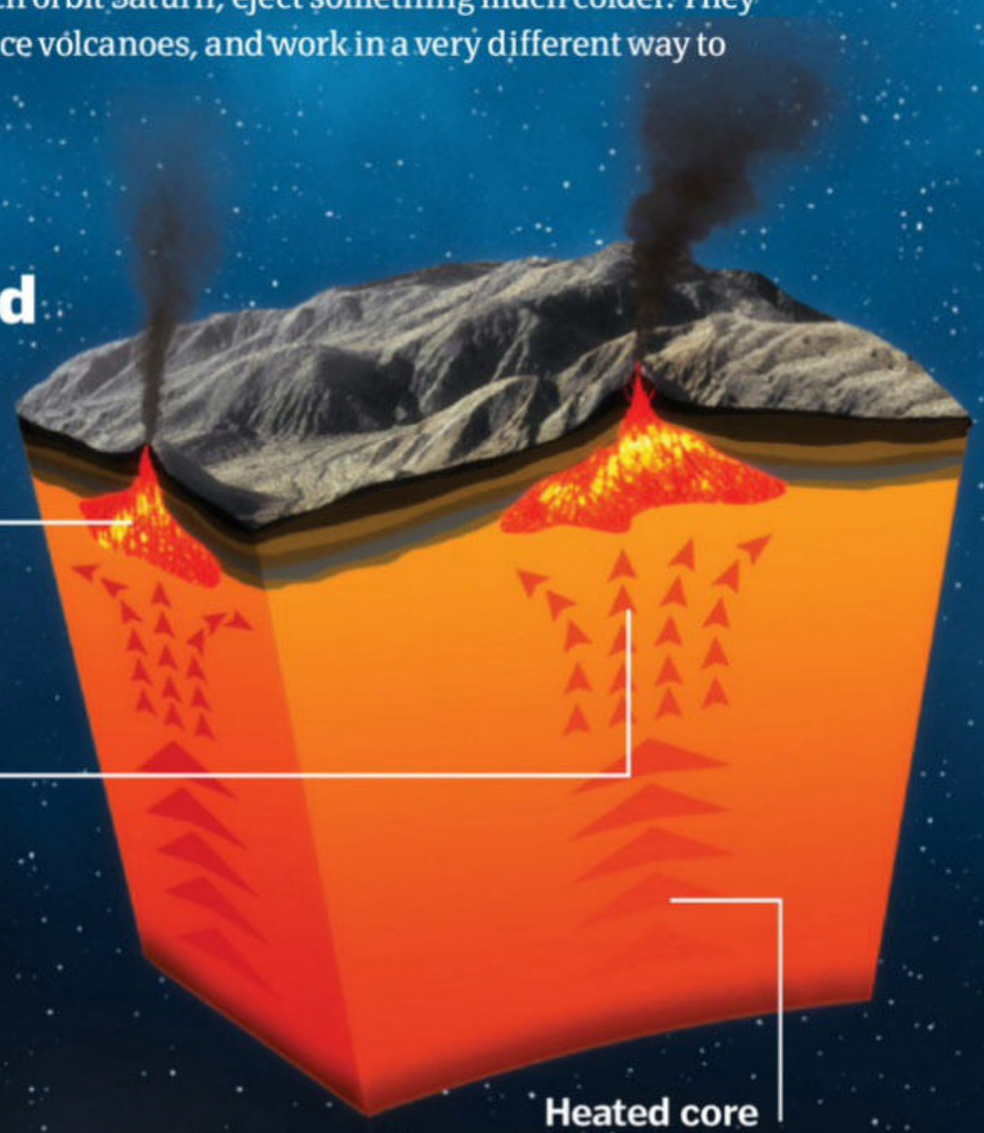
Space volcanoes

Volcanoes can be much cooler elsewhere in our Solar System

It's not just Earth that has volcanoes, they can be found on several other celestial bodies too. The volcanoes on other terrestrial planets like Venus and Mars, and moons such as Jupiter's Io, are very similar to those on Earth, spewing out hot molten rock from below. However, those found on icy moons such as Enceladus and Titan, which orbit Saturn, eject something much colder. They are called cryovolcanoes, or ice volcanoes, and work in a very different way to their hotter cousins.

Hot versus cold

How these two types of space volcano differ

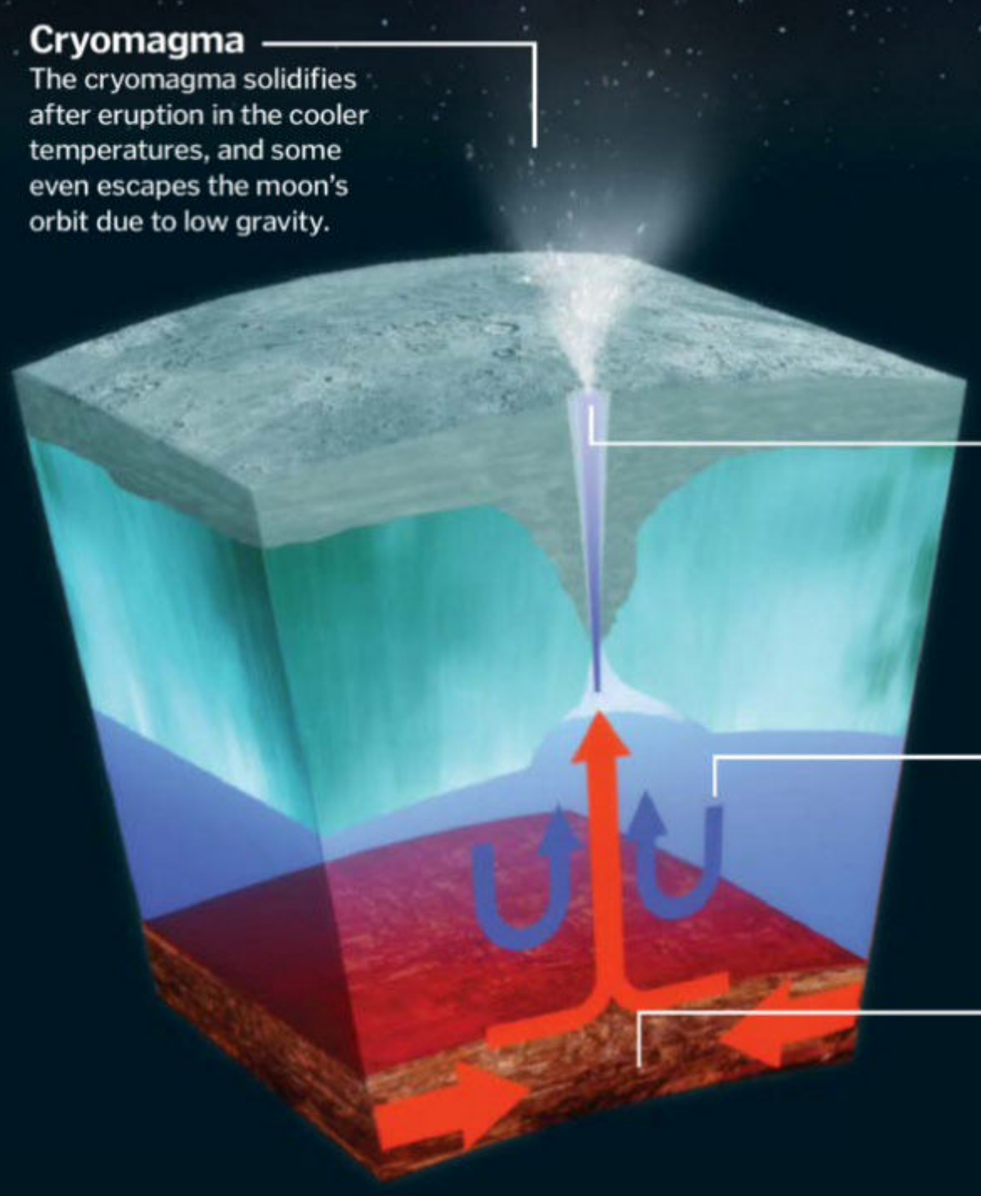


Lava eruption
The magma escapes through vents in the surface and soon cools and solidifies into lava.

Molten rock
Building pressure forces the molten rock, or magma, upwards towards the surface.

Heated core
The planet or moon's core is usually heated by radioactive decay and the residual heat from its formation. However, in Io's case, the moon's heat is generated by tidal friction.

Cryomagma
The cryomagma solidifies after eruption in the cooler temperatures, and some even escapes the moon's orbit due to low gravity.



Icy eruption
A plume of cryomagma; ice particles and water vapour mixed with methane and ammonia, spews out from the moon's surface.

Melted ice
The heated core melts the ice above it, and as pressure builds, it is forced up between ice sheets on the surface.

Tidal friction
Gravity from a nearby planet generates tidal friction that heats the moon's core of silicate rock.

What is a meteor shower?

Discover how falling comet debris becomes shooting stars

A meteor shower occurs when lots of meteoroids enter the Earth's atmosphere one after the other. Meteoroids are bits of dust and rock from comets that are released when their orbit brings them close to the Sun. The Sun's heat boils off some of the comet's icy surface and the resulting debris then trails it in orbit.

Meteoroids that enter the Earth's atmosphere are known as meteors, and can regularly be seen travelling across the sky alone. However, several times each year, the Earth's orbit crosses with the orbit of a comet causing it to collide with a bunch of meteoroids all at once.

Meteors travel through the Earth's atmosphere at very high speeds - up to 72 kilometres (45 miles) per second. Friction of the atmosphere causes the meteor to heat up so the cloud of gas around it glows, and it's this that we see shooting through the sky. As they are usually very small, most meteors burn up in the atmosphere before they reach the Earth's surface, but those that do occasionally hit the ground are known as meteorites.

Meteor showers are named after the constellations they appear to be falling from, such as the Orionids from Orion

© Credit

How to find Polaris

This star has been used as a navigation aid for centuries

Since the 5th century, Polaris has been used to help people find their way when travelling at night. The reason it can be used in such a way is because the Earth's axis points almost directly at it. This means that Polaris remains almost stationary above the northern horizon all year round, while other stars appear to circle around it. It's for this reason that it represents true north.

To find the North Star, you need to identify a group of seven stars known as the Big Dipper. This shouldn't be hard due to this constellation's distinct shape and large size. Unlike Polaris, this constellation's position moves as the stars rotate, so it will appear to be tipped in different directions depending on the time of year. You now need to identify the two pointer stars that form the outer edge of the Big Dipper. By drawing an imaginary line from these two stars up and away from the saucepan shape of the Big Dipper, you will eventually hit the handle of the Little Dipper. The brightest star on this constellation's handle will be Polaris. Knowing the location of Cassiopeia will also help identify the North Star, as it will always lie in between this constellation and the Big Dipper, no matter what time of year it is.

Contrary to popular belief, Polaris was not always located in the north, nor will it remain to be. The Earth's axis is undergoing a process known as precession, which slowly alters the direction in which the axis points, causing the North Pole to point towards a different star. By the year 4000, the effect of precession will make Gamma Cephei our new North Star.

The Big Dipper (Ursa Major)

The Little Dipper (Ursa Minor)

Polaris

Cassiopeia

Polaris is getting brighter

The brightness of Polaris is known to fluctuate, however over the last two centuries it has increased greatly. By comparing it to other stars, scientists now believe that Polaris has become two-and-a-half times brighter in a period of about 200 years. If this is true, Polaris has undergone changes that are 100 times larger than all current theories on stellar evolution predict. The reason for this relatively sudden change is unknown, but is definitely unusual behaviour for a Cepheid variable star.

The shape of the Milky Way

We've never been outside our galaxy, so how do we know what it looks like?

Most of the galaxies close to the Milky Way are also spirals

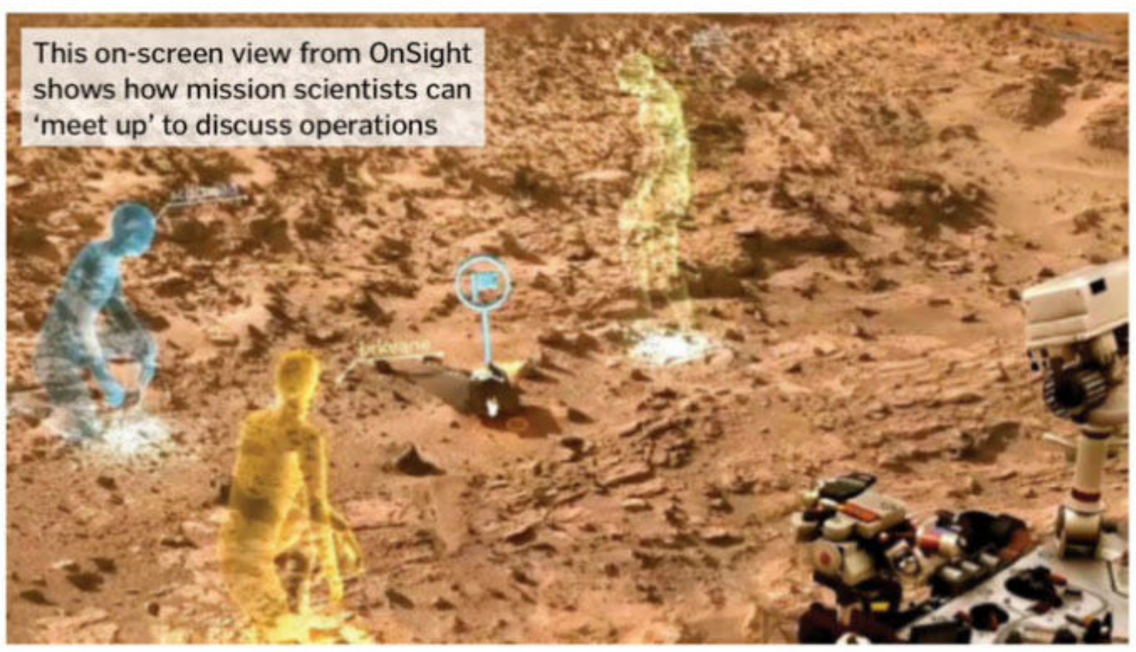
Measuring roughly 100,000 light years across, the Milky Way is mankind's home. Without leaving our galaxy and viewing it from afar, we can't be absolutely certain of its shape, however there is significant evidence that points to it being a sprial. This is just one of four main galaxy shapes that have been observed in the universe, including elliptical, lenticular and irregular.

Looking towards the Milky Way's galactic centre, we're able to see a long, thin strip that suggests we're looking at a disc seen from the edge-on. A central bulge can also be detected, which can be seen in other spiral shaped galaxies. Furthermore, by measuring the velocity of the stars and gas within the Milky Way, it's possible to observe an overall rotational motion that is greater than random motions, which is indicative of a spiral galaxy.

The final clue lies with the amount of gas and dust and their respective colours, which is similar to the other spiral galaxies we've observed. By combining all of this proof, we have fairly conclusive evidence that our galaxy is a spiral.

Working on Mars

Find out how the HoloLens will help conduct science operations on the Red Planet



This on-screen view from OnSight shows how mission scientists can 'meet up' to discuss operations

With the chance to physically walk on Mars still many years away, Microsoft and NASA have worked together to provide scientists with the next best thing. Using the Microsoft HoloLens headset, new OnSight software will use data gathered by the Curiosity rover to simulate Mars' environment, enabling scientists to explore as if they were standing side by side with the rover. Scientists have used pictures to navigate Mars before, by converting them into 3D stereo views. The problem with this had been that scientists struggled to recognise how far away objects were, as depth of vision is very difficult to show. The OnSight system works using holographic computing, which blends a view of the physical world with imagery created by computer, producing a mix of virtual and real surroundings for the user. Scientists can walk around the planet's surface, bend down to closely examine a rock, and even direct the rover to take high-resolution images of interesting areas.

The NASA's Jet Propulsion Laboratory (JPL) plans to use OnSight software alongside the Curiosity rover missions later this year. They are also aiming to use OnSight with the forthcoming Mars 2020 rover.

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Explore Mercury

Learn about the planet of ice and fire

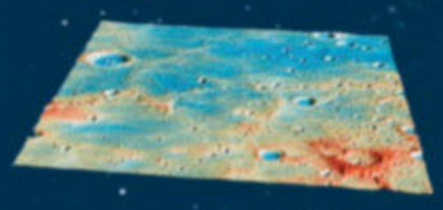
As the nearest planet to the Sun, Mercury is one of the most difficult objects in our Solar System to study. Although you can see it from Earth without a telescope, it is usually lost within the Sun's blinding glare and can therefore only be directly observed at dawn or dusk. However, thanks to NASA's Mariner 10 and Messenger spacecrafts, we now know more about this mysterious planet than ever before. For example, despite its scorching average surface temperature of 167 degrees Celsius (333 degrees Fahrenheit), the planet does in fact have ice at its north and south poles.

Scarred surface

The surface of Mercury looks a lot like that of our Moon as it is covered with craters of varying sizes. These craters are the result of impacts from comets and meteoroids that have been able to penetrate the planet's very thin atmosphere throughout its history. However, unlike the Moon, Mercury's surface also features large areas of smooth terrain as well as tall cliffs called scarps. It is thought that these were created as the planet cooled and contracted when it first formed, leaving wrinkles on the surface ranging from 100 metres (328 feet) to over 1.5 kilometres (0.9 miles) in height.

The Caloris Basin was formed when a 100km (60mi)-wide asteroid hit the planet about 4 billion years ago. It also sent seismic waves across the surface to form hills and mountains on the opposite side of the planet.

The largest impact crater on Mercury is called the Caloris Basin. It is approximately 1,550km (960mi) in diameter, larger than the US state of Texas.



NASA's Messenger spacecraft crashed near Mercury's 400-kilometre (250-mile)-wide Shakespeare impact basin, forming its own crater thought to be 16 metres (52 feet) in diameter.

Missions to Mercury

Mariner 10

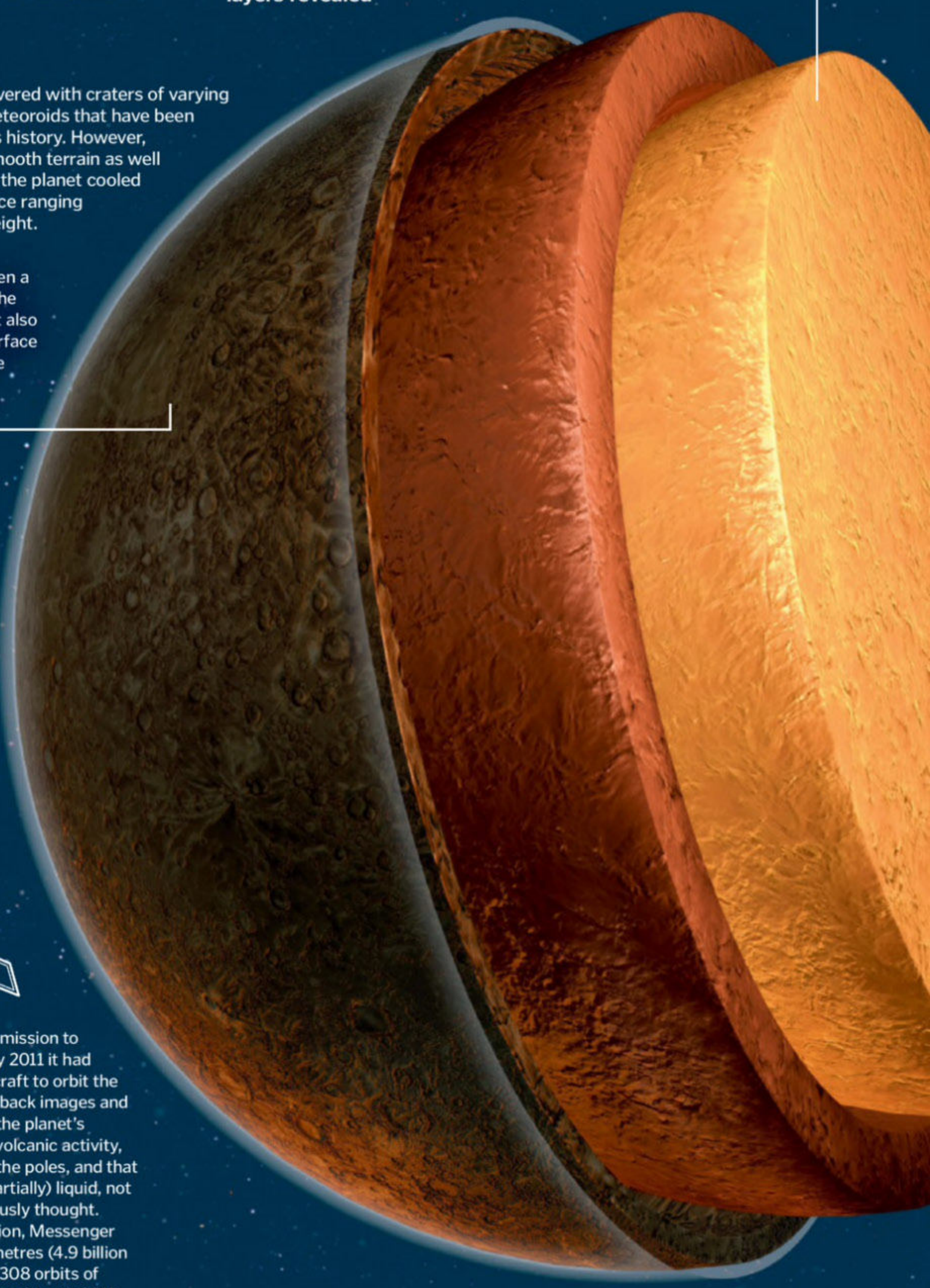
The first spacecraft sent to study Mercury was launched by NASA in 1973. During its mission, Mariner 10 photographed half of the planet's surface, helped scientists discover its magnetic field and revealed its temperature. It was also the first craft to visit more than one planet, as it did a flyby of Venus on the way; the first to use another planet's gravity to alter its speed and trajectory, as its visit to Venus gave it a boost; and the first to make multiple flybys of a planet, as it passed Mercury three times between 1974 and 1975.

Messenger

NASA launched its next mission to Mercury in 2004, and by 2011 it had become the first spacecraft to orbit the planet. Messenger sent back images and data that revealed how the planet's surface was shaped by volcanic activity, large amounts of ice at the poles, and that the core was (at least partially) liquid, not solid as had been previously thought. During its ten-year mission, Messenger travelled 7.9 billion kilometres (4.9 billion miles) and completed 3,308 orbits of Mercury, before finally crashing in 2015.

Inside Mercury

Mercury's Earth-like layers revealed

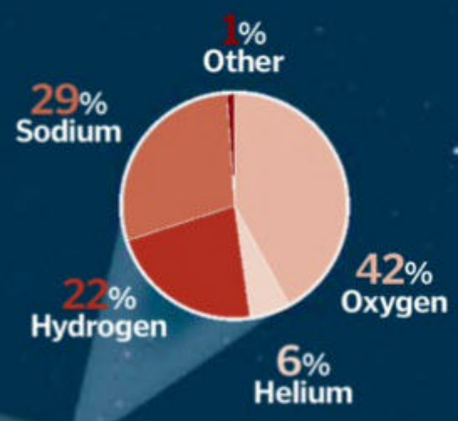


Core
The dense liquid iron core of Mercury accounts for about 70% of the planet's mass.

DID YOU KNOW? *From Earth, Mercury is seen moving across the Sun 13 times a century. The next will be on 9 May 2016*

Absent atmosphere

Mercury's atmosphere is incredibly thin and almost nonexistent. Due to the planet's close proximity to the Sun, strong solar winds blow much of the atmosphere away. However, the planet's magnetic field is able to deflect some of the solar winds away, while its weak gravitational pull holds on to some of the remaining atmosphere.



Extreme temperatures

Being so close to the Sun, temperatures on Mercury can climb to a scorching 430 degrees Celsius (806 degrees Fahrenheit). However, at night they can also plummet to -170 degrees Celsius (-274 degrees Fahrenheit) as the thin atmosphere can't trap much heat in. Temperatures are also extremely cold within the eternally shaded craters at the planet's north and south poles, causing any water present to freeze. It is thought the water could have come from falling comets or vapour from the planet's interior.

During the day, the Sun directly heats the rock.

During the night, the heat of Mercury's rocks is lost rapidly, and the planet's temperature drops.

-183°C (-297°F) **473°C (883 °F)**

Crust
Mercury's crust is ten times thicker than Earth's and is made of silicate rocks.

Magnetic field
Mercury's iron core gives it a magnetic field 100 times weaker than that of Earth.

Mantle
The thin mantle is one-fifth the thickness of Earth's and made of silica-based rocks.

Solid layer
Unlike Earth, Mercury's crust is not divided into tectonic plates because its interior is not hot enough to deform the layer.

Weak gravity

Mercury has just 38 per cent of the gravity here on Earth, similar to that of Mars. This means that you would weigh 62 per cent less there and be able to jump more than twice as high.

Earth
3m (9.8ft) dunk

Mercury
7.8m (25.5ft) dunk

A slamdunk would be much easier for basketball players on Mercury

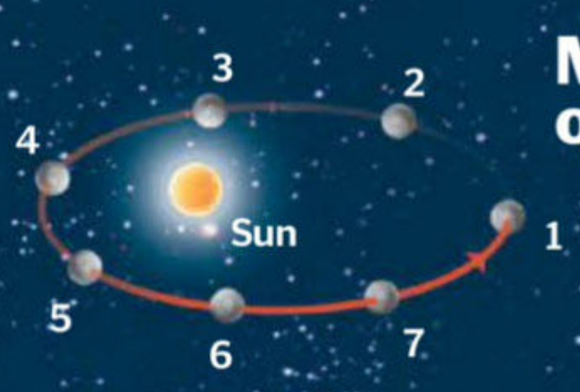
Axis inclination
0.1°
One rotation lasts 59 days

Strange orbit

Mercury's orbit of the Sun takes the shape of an elongated oval as opposed to the more circular orbit of Earth. This means that the planet's distance from the Sun and its speed varies greatly during each orbit. One orbit takes 88 Earth days, but the planet also takes 59 Earth days to spin on its axis. Therefore, someone watching the sunrise on Mercury would have to wait until the planet made two orbits of the Sun, and three rotations on its axis before they could see another one. As a result, one day on Mercury lasts the equivalent of 176 days on Earth, and is actually twice as long as a Mercurian year.

The Sun's motion in the sky would also appear odd if you were on Mercury. The spin of the planet makes the Sun appear to move from east to west in the sky, but its orbit would make it appear to move in the opposite direction. The spin usually wins out, but when the planet is closer to the Sun it moves faster in its orbit, making the Sun appear to briefly reverse in the sky before continuing on its path.

"Mercury can only be directly observed at dawn or dusk"



BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford Uni and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational videogames.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Amy Squibb

Imagine Publishing's Editor In Chief Amy has a passion for gadgets, especially new cameras and photography tech. She's been in publishing for over ten years and loves to write about science, history, technology and more.

Shanna Freeman

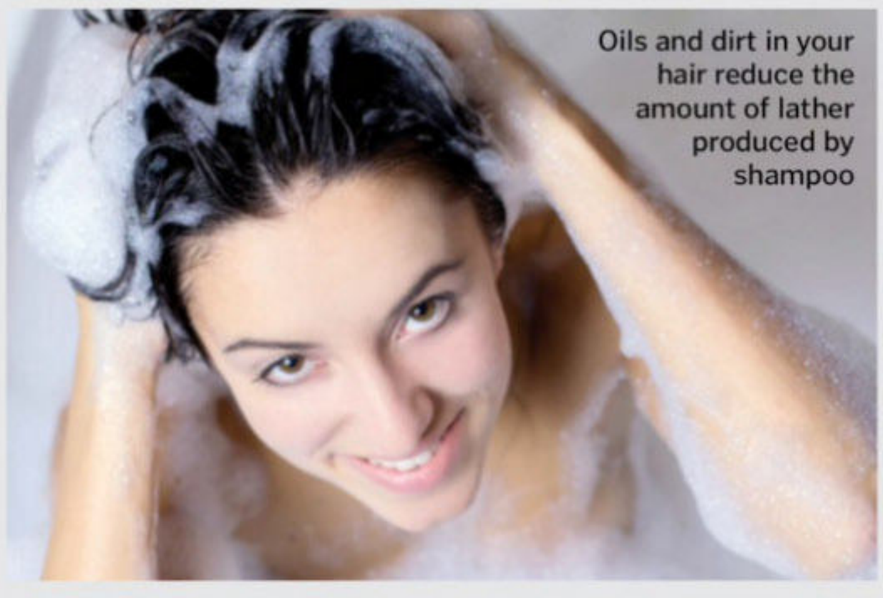
Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Ex-planet Pluto could have been called Atlas, Constance, Cronus, Minerva, Percival or a number of other names

How are the names of planets chosen?

Colin Noble

■ Planetary names in our Solar System are derived from mythology – except for Earth, which comes from Middle English. Since five of the planets can be seen by the naked eye, they have been called many things depending on the culture over the centuries before their current names became standard. Uranus (previously thought to have been a star) is the only planet whose name comes from Greek rather than Roman mythology. Neptune's discoverers argued over who could name it, while former planet Pluto's name was suggested by an 11-year-old in the UK. There were no planetary naming rules until 1919, when the International Astronomical Union (IAU) formed. The IAU is currently in charge of naming all celestial objects. **SF**



Oils and dirt in your hair reduce the amount of lather produced by shampoo

Why do you get more bubbles when you shampoo a second time?

Natalia McLaren

The first time you shampoo your hair, oils from your scalp stop bubbles from forming, but this effect ceases once these oils have been washed out. The foam in shampoo is created by surfactants, typically sodium lauryl sulphates. These chemicals allow oil and water to mix, making the oil and dirt from your hair soluble into water and allowing them to be rinsed out. When you first lather up, most of the surfactants cling to oils and therefore don't form many bubbles, but by the second time around your hair is cleaner, meaning that the surfactants can create more foam. **AC**

FASCINATING FACTS

Where did the word 'king' come from?

There's some debate about the origins of the word. It may come from the Old English 'cyning'. 'Cyn' meant 'kin' and 'ing' meant 'son of' likely indicating the hereditary nature of the ruling monarchy.

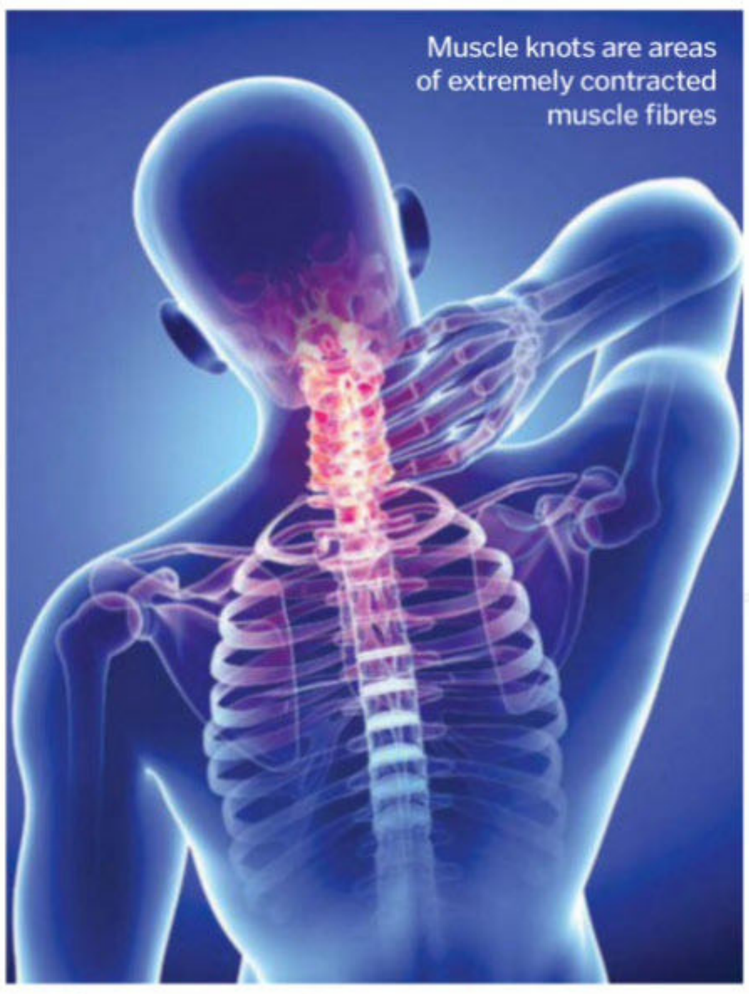
Lucius Tarquinius Superbus was the last king of Rome before the monarchy was overthrown around 509 BCE

What is the history of the beard?

Skye MacMillan

■ Beards are currently trendy, but their popularity has cycled. Prehistoric men are believed to have had thick beards for protection from both the elements and other men during fights. They also may have been an intimidation factor, as they made the jaw look bigger and more menacing. Beards have often been said to project a strong sense of masculinity, and a big beard was a sign of honour in ancient times. Cutting off one's beard was used as a punishment. Then things changed around the time of Alexander the Great, in the mid-300s BCE. He banned beards on his soldiers because he feared that enemies could use them to pull them in for attack. In the Middle Ages, it was considered highly offensive to touch another man's beard and could lead to a duel. In the 18th century, beards fell out of favour, then returned during Victorian times. Beard wearing has had – and will continue to have – many different influences, including politicians, celebrities, religion and societal changes. **SF**

Hans Langseth, pictured here in 1912, grew his beard to a record-setting 5.33 metres (17.5 feet) long



Muscle knots are areas of extremely contracted muscle fibres

What are 'knots' in muscles?

Paloma Skinner

■ The knots that masseurs knead out of people's backs are regions of contracted muscle. The muscle fibres become extremely short and compressed, and as a result feel thick and hard. When several contraction knots occur together, it can form a tender lump known as a myofascial trigger point. This area of hypersensitive muscle is painful to touch, and because the section of the muscle is under constant tension, it can restrict its range of movement, preventing it from stretching out to its full extent. **LM**

Ikea now includes wireless charging pads in some of its lights and furniture

How does wireless charging work?

Elaine Faulkner

■ Most wireless chargers use electromagnetic induction. The charging pad contains a wire coil, and an alternating electric current is passed through the coil to create a pulsing magnetic field. At the other end, your mobile phone has its own coil, which reacts to the magnetic pulses by producing a corresponding alternating electric current. This is converted into direct current to power the device. Wireless charging is less efficient than cable charging and the device needs to be very close to the charger because magnetic field strength falls off very quickly with range. But recently, a company called uBeam has demonstrated longer range wireless charging that works by beaming ultrasound waves that are converted into electricity in your phone by piezoelectric transducers. Starbucks is thought to be in talks with uBeam to include ultrasound chargers in its coffee shops, but you'll need a special ultrasound receiver for your phone. **LV**

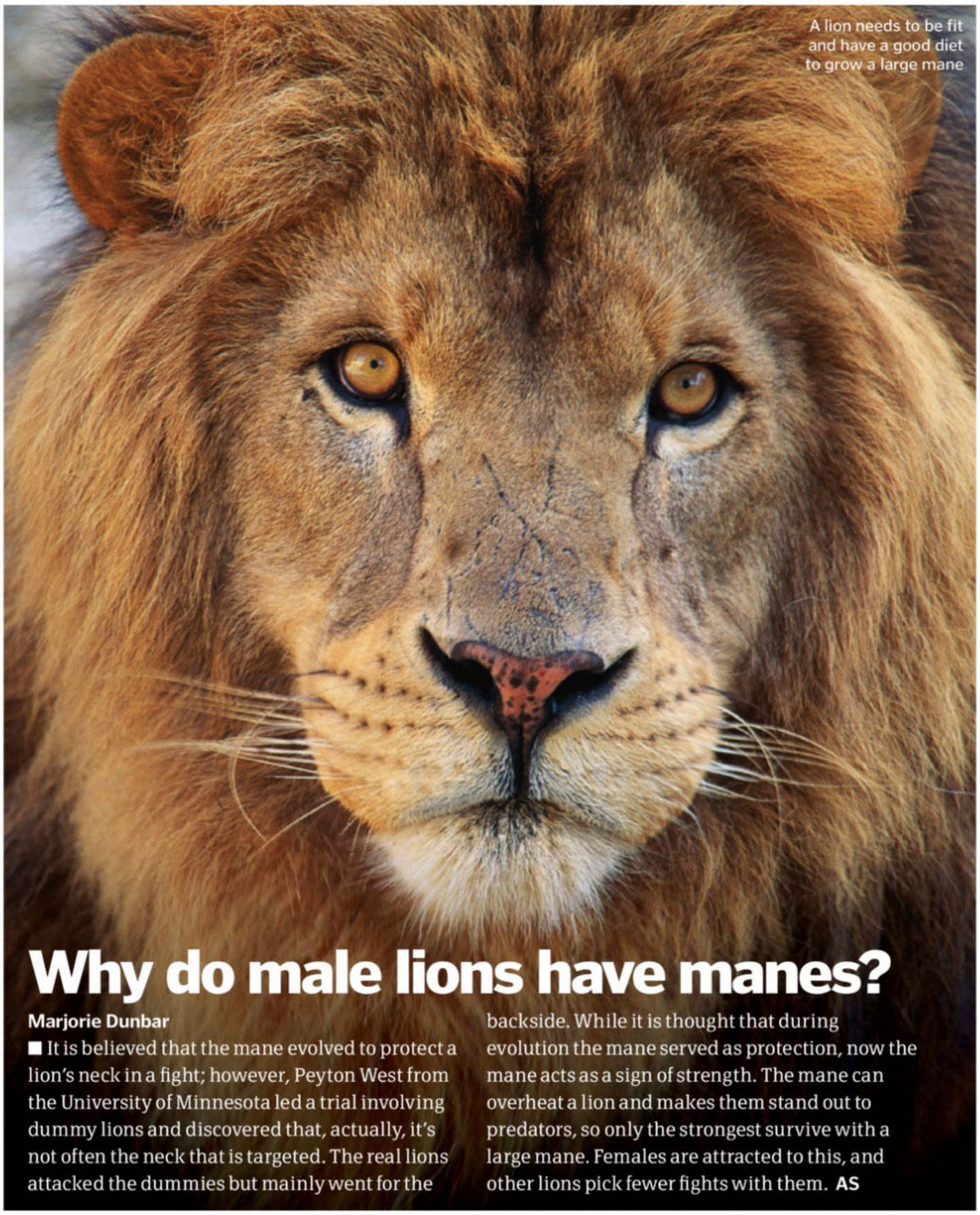
Why don't spiders stick to their own webs?

Elliot Forsyth

■ Not all the threads on a spiderweb are sticky. The spokes of the web pattern are made from a dry, structural silk and spiders mostly walk on these threads as they move around the web. But they also need to be able to handle the sticky spiral threads when building and repairing the web, without getting stuck themselves. They can do this because their legs are covered with stiff bristles that minimise the surface area in contact with the sticky droplets. They also have an oily substance that repels the adhesive and acts as a non-stick coating. **LV**

Spiders also have a special kind of silk just for wrapping their prey

BRAIN DUMP

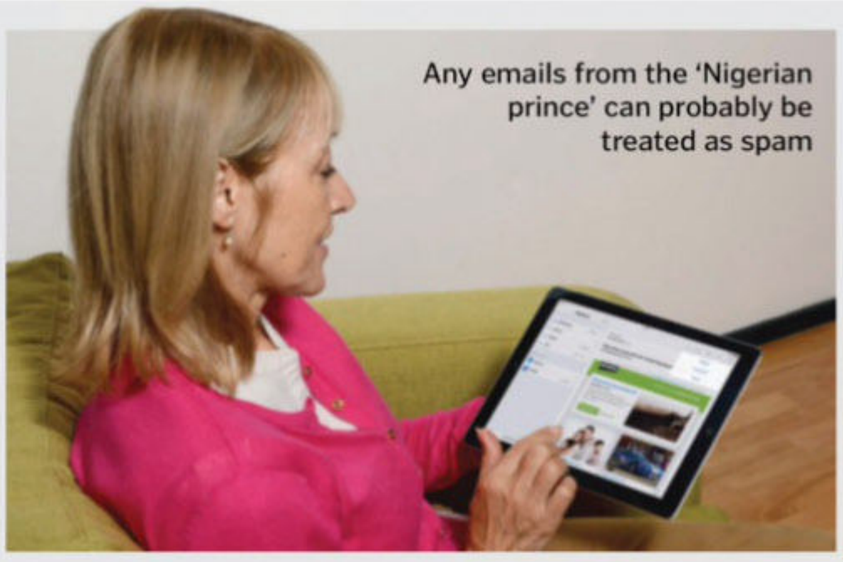


A lion needs to be fit and have a good diet to grow a large mane

Why do male lions have manes?

Marjorie Dunbar

■ It is believed that the mane evolved to protect a lion's neck in a fight; however, Peyton West from the University of Minnesota led a trial involving dummy lions and discovered that, actually, it's not often the neck that is targeted. The real lions attacked the dummies but mainly went for the backside. While it is thought that during evolution the mane served as protection, now the mane acts as a sign of strength. The mane can overheat a lion and makes them stand out to predators, so only the strongest survive with a large mane. Females are attracted to this, and other lions pick fewer fights with them. **AS**



Any emails from the 'Nigerian prince' can probably be treated as spam

How does my computer decide what is junk mail?

Claudia Packham

Junk mail, or 'spam', is detected by scanning the message for common warning signs. Was the message sent from a blacklisted network? Have the headers been tampered with to hide the sender? Does the subject line use all capital letters? Are there lots of exclamation marks? Do phrases such as 'click now!' or 'lowest prices' appear in the message itself? These are added together to give a weighted score, and anything over a certain number is deemed to be spam. If you manually mark an email as spam, it also refines the scoring system for future emails. **LV**

FASCINATING FACTS

Where do sesame seeds come from?

Sesame seeds come from the Sesamum indicum plant, found native in Africa and Asia. The plant bears capsule-like fruit and the seeds are found inside, much like peas in a pod.

The plants that bear sesame seeds are one of the oldest known to man

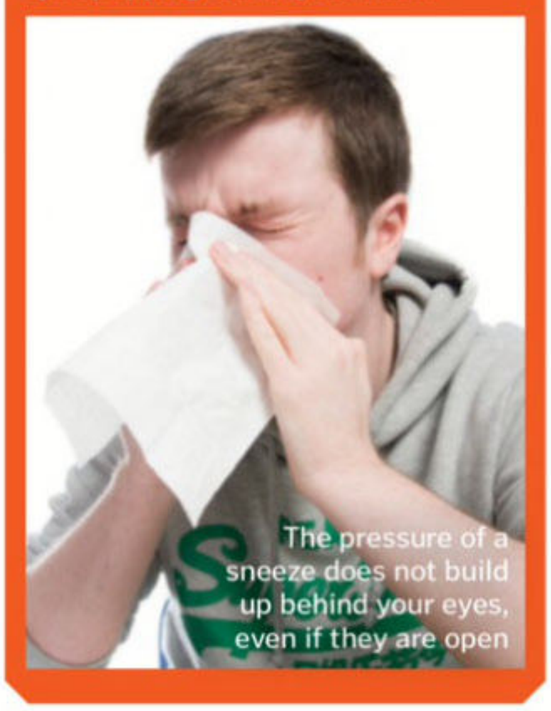
What colour is a mirror?

In theory, a perfect mirror is white as it reflects all colours of light equally. However, unlike other white objects, mirrors reflect light in a single direction rather than scattering it.

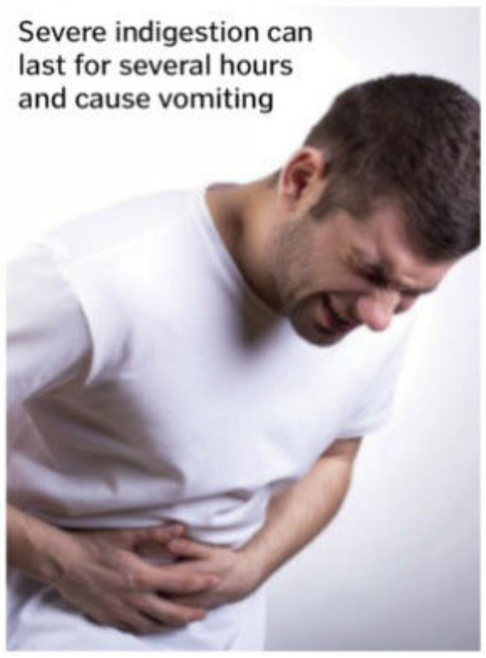
Most mirrors reflect green light more and so have a green tinge

Can you sneeze with your eyes open?

Some people can. Blinking during a sneeze is a reflex, but even if you don't blink there is no danger of your eyes popping out of your head.



The pressure of a sneeze does not build up behind your eyes, even if they are open



Severe indigestion can last for several hours and cause vomiting

What is indigestion?

Zack Riley

Indigestion (also known as dyspepsia) is a pain in your stomach after eating. It's caused by the acid in your stomach coming into contact with the lining of the digestive system (the mucosa). This lining is sensitive and can be irritated by the harsh acid, which breaks it down and can also cause it to swell, leading to the discomfort you feel.

Indigestion is most often triggered by eating, but can also be caused by smoking, drinking, stress or certain medications. It is often treated with antacids, which neutralise the acid made by your stomach and helps relieve the pain. **AS**

Why do drinks taste strange after brushing my teeth?

Chris Larkin

The strange taste of food and drinks after cleaning your teeth is down to the chemistry of the toothpaste. Most contain a chemical known as sodium lauryl sulphate (SLS), a surfactant that works in a similar way to washing-up liquid to make your toothpaste froth. Scientists think that this chemical might also interact with your taste buds. SLS makes sweet food taste less sweet, and it breaks down molecules known as phospholipids, which make bitter food taste less bitter. The result is that your orange juice tastes less sugary and more unpleasant. **LM**

A chemical in toothpaste changes the way your tongue senses sweet and bitter tastes

Temperature is measured most often in degrees Celsius, Fahrenheit or Kelvin

What is the difference between heat and temperature?

Rufus Webster

Heat (measured in joules) is the amount of thermal energy (molecular movement) something has and it can vary depending on the mass of the object; if the object has a large mass, its thermal energy will also be large as it has a lot of molecules, while a smaller object will have less thermal energy as it has fewer molecules. Temperature, however, is a measure of the *relative* thermal energy of something; it's the degree of hotness or coldness, measuring the average kinetic energy in the molecules of an object. Temperature is not dependent on the mass of an object, so objects of different sizes could have the same temperature, but they'd have different heats. For instance, a mug of tea may have the same temperature as a bath of hot water, but as the bath has more water, it takes more energy to get its molecules to that temperature, and therefore it has more heat. **AS**

Why does tarmac have that mirage effect even if it's not a particularly hot day?

Stuart Dent

Although they're often associated with deserts and summer temperatures, it doesn't have to be a particularly hot day for you to see a mirage on dark tarmac – just a sunny, dry one. Mirages are caused by waves of light passing through layers of air that have different densities, then refracting – or bending – towards the densest layer of air. In an inferior mirage, the layer of air on the surface is warmer than the air above it, creating an image below that of the actual object. This is why you can often see mirages on road surfaces because tarmac heats up quickly on a sunny day. **SF**

This image was taken in Apeldoorn, the Netherlands, in May, when the average high temperature is 13°C (55.4°F)

BRAIN DUMP

Not all frogs and toads are as easy to distinguish, leading to some debate

What's the difference between frogs and toads?

Betty Martinez

Frogs and toads share many features, so they are often confused. They both belong to the Anura order of the class Amphibia, but they usually have features that help to separate them. Frogs have long legs to enable them to jump and mucus-covered skins. Toads are fatter, have dry skin, and have shorter legs. Frogs tend to stay close to water while toads are more often found inland. While this category is huge, we tend to think of 'true frogs' as members of the Ranidae family, and 'true toads' as members of the Bufonidae family, each of which contains hundreds of different species. **AS**

FASCINATING FACTS

Is there an animal with only one eye?

Yes, and they are very common in the UK. The Cyclops genus of copepods is freshwater crustaceans between 0.5 and 5 millimetres (0.02 and 0.2 inches) long, each with a single red or black eye.

The small red dot at the front of this cyclops larva is its single eye

Why do some people have wisdom teeth?

Sarah Presly

If you trace human evolution right back to our early ape-like ancestors, you'll find that they had much larger heads and jaws than we do now. Their teeth would have been used for biting, crushing and grinding food well before we had developed the means to chop and cook it. As we evolved and our diets changed, our teeth were no longer our primary tool, and as our brains grew larger, our jaws became shorter.

Today, we no longer need our wisdom teeth, and for many people they are a problem. Our jaws are small, and wisdom teeth don't always have space to come through straight. They often need to be removed because they are causing pain, or damaging the surrounding teeth. Around 35 per cent of the population do not have any wisdom teeth at all, and there is some debate as to whether they will eventually disappear all together. **LM**

Wisdom teeth are no longer necessary, and in many people they are a source of pain and discomfort

Why is it dangerous to look directly at the Sun?

Kyle Lewis

The Sun's light contains far more energy than our eyes can safely absorb, and it can damage the eye's delicate structures within seconds. Staring directly at the Sun for a few seconds typically causes photokeratitis, a condition similar to sunburn, which leads the cornea to become cracked and inflamed. Though it is very painful, patients usually recover fully. Longer exposure can damage the retina, causing vision to become blurry or discoloured for several months. Eyesight may never return to normal. Damage to the macula, a portion of the retina used for detailed vision, can result in permanent loss of visual acuity. **AC**

You can look at the Sun safely using special glasses intended for this purpose

Some people smell more attractive to mosquitoes than others

Why are some people more prone to mosquito bites?

Fraser Dunn

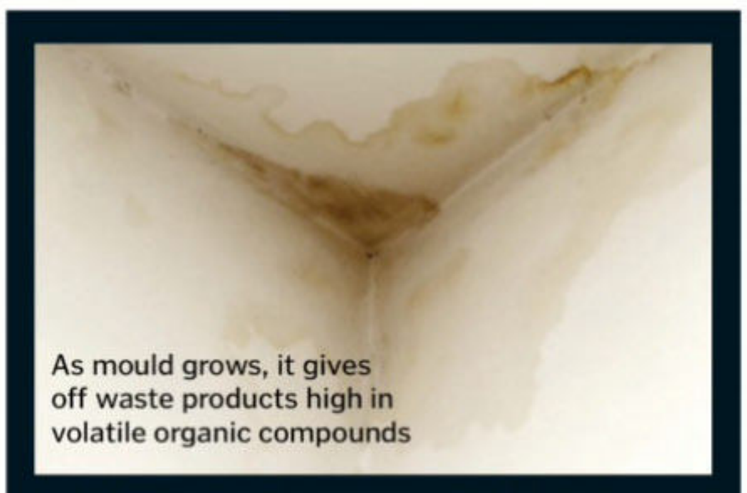
■ Many insects are attracted to certain smells, and mosquitoes are no exception. In 2015, researchers at the London School of Hygiene and Tropical Medicine proved a genetic link to scent and mosquito bites. They looked at 18 sets of identical twins and 19 sets of non-identical twins and measured how attracted mosquitoes were to their smell. With identical twins, the mosquitoes preferred both equally, but with non-identical twins they tended to prefer one to the other, indicating that some people carry the genes for a natural insect repellent. **LM**

Microwave ovens have two separate interlocks to shut them off when you open the door

Is it unhealthy to stand in front of a microwave?

Jeremy Daly

The glass door of a microwave oven is backed by a metal mesh with holes about 1 millimetre (0.04 inches) across. This is much smaller than the 12-centimetre (4.7-inch) wavelength of microwaves, so they are blocked. A tiny amount of radiation leaks through, but manufacturing regulations limit this to just five milliwatts per square centimetre, at a distance of 5 centimetres (2 inches) from the oven. Microwaves are non-ionising radiation, so there's no cancer risk; the only danger comes from the heating effect and 5mW/cm^2 is weaker than sunlight. **LV**



As mould grows, it gives off waste products high in volatile organic compounds

What is the smell of damp?

Sharon Ray

■ Moisture allows molecules to reach our noses more efficiently, and also provides the ideal conditions for bacteria and mould to grow. When you detect a smell, this means that 'smelly' organic compounds have travelled through the air and been inhaled into your nose. These organic compounds dissolve into water, and enter the air much more easily as the water evaporates, meaning that dampness amplifies smells. Laundered clothes for instance smell more when they're still damp. Additionally, when damp conditions persist, it creates the perfect environment for bacteria and mould to thrive, giving off volatile compounds with that characteristic musty smell. **SB**

What is déjá vu?

Matt Yuen

■ Déjá vu affects 70 per cent of people, but scientists have identified no definite explanation for why it happens. The phenomenon involves a feeling of familiarity in a situation where you are in fact experiencing something new. Since this typically occurs very fleetingly, it is difficult to study. Déjá vu is most common in young adults, leading experts to suspect that it may be linked to dopamine levels, which are generally higher in 15-to-25-year-olds. Episodes of déjá vu occur very consistently before a certain type of epileptic seizure. This suggests that déjá vu, like an epileptic seizure, could be caused by brain cells misfiring, transmitting electric signals at random and generating a false sense of familiarity. Another theory is that familiar features, for example the layout of a shop, may be recognised by the brain without us realising, triggering feelings of familiarity in a new situation. **LM**

Déjá vu may be the product of neural misfiring in the brain

Astronauts must show their passports, just like everyone else

Do astronauts go through customs when returning from space?

Silvia Hackford

■ Yes, but not simply because they're returning from space. Currently astronauts spending time on the International Space Station must travel to and from the Baikonur Cosmodrome in Kazakhstan because they launch on the Russian Soyuz spacecraft. They go through international customs like everybody else. There are customs forms filled out for the Apollo 11 astronauts, but it was for novelty purposes only. It's likely that the forms were created as a joke by a Customs Services District Director in Hawaii (the closest state to the splashdown location) and later signed using an autopen. **SF**

Travel accessories

We unpack the gadgets that can take the hassle out of a long haul flight or an overseas work trip

These days almost everyone undertakes some form of travel, whether that is for an annual family holiday or simply commuting to and from work. Due to this, the number of travel gadgets and accessories has exponentially increased; almost everything has been adapted to work on the move or away from home. We've selected a range of products that might make your next trip easier, or slightly more enjoyable.

Checklist

- ✔ Bluetooth mouse
- ✔ Satellite communicator
- ✔ Exercise solution
- ✔ Portable charger
- ✔ Headphones
- ✔ Multi-tool
- ✔ Suitcase

1 Ultimate portability

Microsoft Arc Touch Bluetooth Mouse
£59.99 / $69.95
www.microsoftstore.com
Packing a standard sized mouse for travel may not seem to be much of an inconvenience, however the Arc Touch Bluetooth Mouse from Microsoft is a much better alternative. Its sleek design is excellent, and its ability to fold flat makes it easy to pack into any bag. There are cheaper alternatives available, but they are unlikely to be as reliable or as ergonomic as this mouse.
Verdict: ✿✿✿✿✿

2 Worldwide coverage

DeLorme inReach SE
£225 / $299.95
www.inreachdelorme.com
The inReach SE from DeLorme is the ultimate in personal satellite communication. Its rugged design makes it tough enough for even the most extreme of expeditions, and its 100-hour battery life means it can last short trips without being recharged. Many may consider this device to be too expensive, but if you are planning on any trips to remote locations the inReach SE won't let you down.
Verdict: ✿✿✿✿✿

3 Portable fitness solution

FitKit
$34.99 (approx £23)
www.amazon.com
Keeping fit when travelling can be difficult; hotel gyms are notoriously unreliable and sometimes poorly equipped. The FitKit provides a compact, effective way of keeping active when away from home, and offers a range of exercises that cover cardio, strength and flexibility. Access to an online library of exercises means you'll never run out of options, and it's priced very reasonably.
Verdict: ✿✿✿✿✿

4 Rapid charging

Cobra JumPack
£79.99 / $149.95
www.cobra.com
There's a multitude of portable chargers now available, but few claim to possess the power of the Cobra JumPack. It has a battery capacity of 7,500 milliampere hours, and even has an LED flashlight built for emergencies. It will comfortably charge your mobile devices, and is small enough to take travelling. The white and lime green design might not be for everyone though.
Verdict: ✿✿✿✿✿

Sleek case
The case design is sleek and simple, and is small enough to fit comfortably into any suitcase or bag.

32 configurations
The suitcase works in an impressive 32 different configurations, allowing it to adapt to the owner's needs.

Accurate to five metres
The accuracy of the inReach SE is very impressive, and could prove vital in an emergency situation.

Two-way touch scrolling
The scrolling pad is a nice feature, and is easier to use than many laptop touchpads.

5 Collapsible headphones

AKG Y45BT White
£109.99 / $180
www.amazon.com
A quality pair of headphones is a must for any seasoned traveller. The Y45s from AKG offer both wired and Bluetooth connectivity, which is great when you use a variety of devices, or when they run out of charge. The sound quality is unfortunately only average at best, but the on-ear design makes them very comfortable to wear.
Verdict: ✪✪✪✪✪

6 18 tools in 1

Wallet Ninja
£8.99 / $9.99
www.walletninja.com
The creators of the Wallet Ninja really have thought of everything. Roughly the size of a credit card, it is made of heat-treated steel, and comes with a lifetime guarantee to never rust or bend. It has an impressive 18 tools, including a bottle opener, ruler and eyeglass screwdriver, all of which you might need when travelling. All of the tools work well, making this gadget hard to fault.
Verdict: ✪✪✪✪✪

7 Suitcase

Victorinox Werks 5.0 Traveller 20 Dual-Caster suitcase
£280 / $620
www.amazon.com
The 20 Dual-Caster suitcase from Victorinox works well to meet a traveller's needs. It has nice external compartments; the zippers are smooth, the wheels function very nicely, and the storage is ideal for a carry-on bag. The price reflects the quality of this suitcase; if you're a serious traveller and often only take carry-on luggage, this is an excellent choice.
Verdict: ✪✪✪✪✪

EXTRAS

Make sure you're fully prepared...

BOOK

747 Things to Do on a Plane

Price: £8.99 / $10.95
Get it from: www.amazon.com
This clever book's primary aim is to fight the inevitable boredom we've all experienced at 30,000 feet. It's packed full of different ways to keep yourself entertained on a long flight, and is just as entertaining as watching a film or listening to music.

APP

XE Currency

Price: Free
Get it from:
iTunes and Google Play
This currency conversion app is one of the most accurate around as it uses live currency rates, enabling you to easily find out how much foreign currency you should be getting for your money. It has been downloaded more than five million times to date.

WEBSITE

Flight search

Website: www.adioso.com
This flight search engine is ideal for those of us that are flexible with when we fly. You can type in a request, for example 'London to Washington next week under £700' and see whether there are any flights that match these criteria.

GROUP TEST

Putting products through their paces

With these cameras you can record all the highlights of action-packed days out

Action cameras

Record high-quality footage of your latest stunts with these rugged camcorders

Waterproof housing
The Elite is waterproof to 1m (3.3ft) but the optional dive case extends this to 50m (164ft).

Remote control
The Ghost-S comes with a remote control that can be used to operate one or multiple cameras.

Tag yourbest bits
HiLight Tag lets you mark key moments while recording so you can find them easily in playback.

HOW IT WORKS EDITOR'S CHOICE AWARD

1 Garmin VIRB Elite

Price: £219.99 / $269.99
Get it from: www.garmin.com
Garmin's chunky VIRB Elite fits comfortably in your hand and the rubberised design allows for a good grip in wet conditions. The large buttons are also easy to press even if you're wearing gloves, and you can switch on and start recording with a simple slider, although it is slow to spring into life. The 3.6-centimetre (1.4-inch) screen isn't backlit, so it is a little dim and difficult to view, but this helps extend the battery life to almost three hours. The camera can also be controlled remotely via your smartphone or a Garmin watch. The Elite's real unique selling point though is that it has built-in GPS, an accelerometer and a barometric altimeter to record extra info with your footage, and it can link up with many other Garmin external sensors to record things such as your heart rate, too. This, coupled with the impressive image quality, make it a great camera, but you have to pay extra for many accessories, such as waterproof housing.
Verdict: ✪✪✪✪✪

2 Drift Ghost-S

Price: £329.99 / $399
Get it from: www.driftinnovation.com
The solid Ghost-S is waterproof up to three metres (ten feet) without a case, but if you want to use it in deeper waters then the optional housing extends this depth to 60 metres (197 feet). It's watertight body requires the battery cover be screwed on very tightly, making it hard work to take off again, and the buttons also require a bit of strength to push, so scrolling through the long menus can get quite tiring. However, once you're set up, the camera delivers 12-megapixel stills and smooth 1080p HD video at 60 frames per second with a good amount of detail throughout. The wide-angle lens can be rotated to enable you to use the camera in any orientation, although you will need a screwdriver handy to do this, and it features a 10x digital zoom, something not available from the competition. Cutting in slightly cheaper than the GoPro, the Ghost-S is a worthy alternative with a much longer battery life, so long as you don't mind it's slightly brick-like, chunky design.
Verdict: ✪✪✪✪⚙

3 GoPro Hero4 Silver

Price: £329.99 / $399.99
Get it from: www.gopro.com
Despite being the smallest action camera on test, the GoPro still delivers very impressive image quality and can even shoot 4K videos at 15 frames per second. However, 60 frames per second can be reached with 1080p HD video recording, extendable to 120 frames per second at 720p, so you can capture smooth and slo-mo footage. Time Lapse and Night modes also aid creativity and Protune enables lots of manual control over stills and video. A lack of digital image stabilisation makes footage a little shaky, but the wide-angle lens gives you plenty to crop in to. The small, bright touchscreen on the back makes adjusting settings easy, or you can use your phone as a remote control via Wi-Fi and Bluetooth, but both of these features drain the battery so carrying a spare is advisable. The GoPro may be an expensive option, but you get great image quality and a lot of features for your money, plus the waterproof housing that can be used to a depth of 40 metres (131 feet), is included in the price.
Verdict: ✪✪✪✪⚙

Wrist control
The Rollei wireless wrist remote works up to 15 metres away from the camera.

Extreme conditions
The WG-M1 can withstand temperatures down to -10°C (14°F) and be dropped from a height of 2m (6.6ft).

4 Rollei Actioncam 400

Price: €129.99 (approx £95 / $145)
Get it from: www.rollei.com

Rollei's Actioncam is only slightly bigger than the GoPro but less than half the price, making it ideal for those on a budget. There is a slight but noticeable dip in video quality, and sadly there is no option to take still images, but 1080p footage can still be recorded at a decent 30 frames per second. Navigating the menu is a little complicated with very few buttons to use, but there are some useful features, such as Time Lapse mode, tucked away in there somewhere. The rubberised body feels tough and durable, and the supplied waterproof housing enables it to be used down to depths of 40 metres (131 feet). In the box you get a whole host of handy mounts and accessories, but one particularly useful addition is the supplied wrist strap that can be used to remotely control the camera. This means that you can easily start and stop recording while on the move without having to fumble for the camera button or get your phone out.

Verdict: ✿✿✿✿✿

5 Ricoh WG-M1

Price: £199.99 / $199.95
Get it from: www.ricoh-imaging.co.uk

The Ricoh WG-M1 certainly looks the part, with a solid and chunky rugged design that is shock-resistant, cold-resistant and waterproof to a depth of ten metres (33 feet) without a case attached. Its dual-lock battery compartment is much easier to open than the Drift's, but still feels secure and a lens cover is supplied to make it even more watertight. The video quality is on par with the Rollei, delivering smooth 1080p 30 frames per second footage, but it struggles with bright conditions, blowing out the highlights and capturing unusual colour casts. It can, however, capture 14 megapixel photos too, and shoot a burst of them at ten frames per second. The battery only lasts for about 150 minutes when recording and finding your way around the settings is quite long-winded, as you're required to scroll through all the available options before you can return to the main menu. Nevertheless, the WG-M1 is very reasonably priced, but be aware that it comes with only one mount.

Verdict: ✿✿✿✿✿

Action cameras are designed to be able to withstand the inevitable knocks and bumps of adventurous activities

Recording watersports is no problem at all, as most action cameras feature waterproof housing

ON THE HORIZON

Tough cams

Panasonic HX-A1ME

This compact wearable camera is waterproof, shockproof, freezeproof and dustproof and even has an infrared night mode for filming in the dark.

Sony AZ1VR

Sony's splashproof action cam comes with a live view remote that you can strap to your wrist, so you can see what you're filming from a distance.

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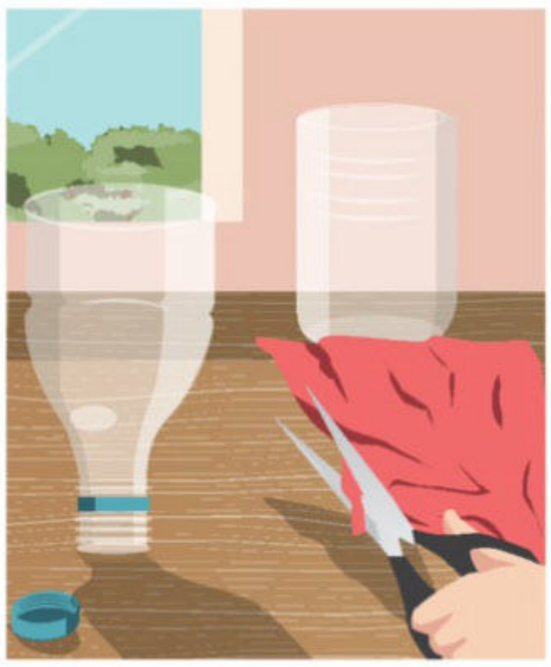
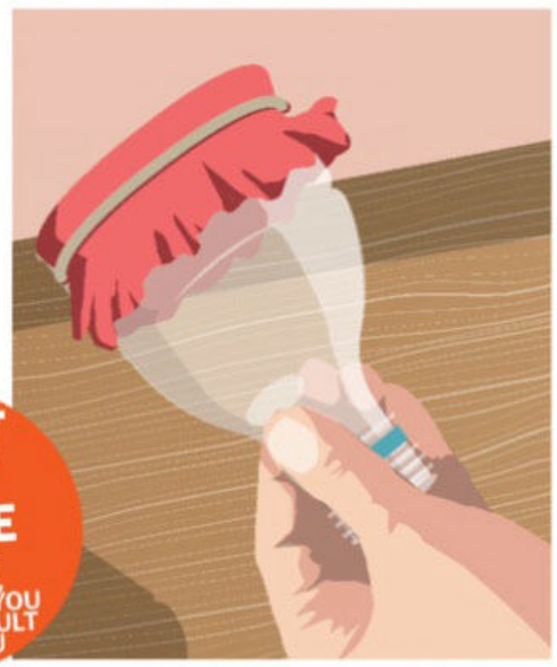
Build a lung
Turn everyday household items into a working lung model



1 Cut your bottle
With the help of an adult, cut the two-litre (0.5-gallon) bottle in half. Discard the bottom half and the lid as you will only need the top half for this experiment. Cut a square of plastic from a shopping bag and make sure it is big enough to cover the bottom of the cut bottle. The edges don't need to be perfectly straight so don't worry about being too neat.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



2 Secure your plastic sheet
Stand the bottle on its top, and place your cut plastic over the large, open end. With the help of a rubber band, secure your cut plastic around the bottle. Carefully pull the edges, so that a taught surface is formed across the top. Once you are happy with this, you can trim off the excess plastic. This represents your diaphragm, the muscle that contracts and relaxes, forcing your lungs to fill with air and then empty.

3 Build your breathing mechanism
You are now ready to add your breathing mechanism. Place a straw inside a balloon, which will act as a lung. Next, secure the straw in place with plenty of tape, as this seal will need to be airtight. Now test the seal by blowing into the straw; if the balloon doesn't inflate slightly then the seal needs to be improved by being tightened up some more.

4 Install your lung
Drop the balloon end into the bottle's opening. This needs to be secured in place, which can be achieved using modelling clay. Press the modelling clay down firmly to create a seal, which must be completely airtight just like we did with our tape and straw in Step 3. The model won't work if air is able to enter the bottle by any other means than the straw.

5 Complete your model
The final step is to add a means of moving the plastic sheet up and down. Adding a sticky tape 'tab' to the bottom of the plastic will achieve this. Take a piece of tape and fold it in half, so that the sticky sides are together and the ends are left exposed. Stick the exposed ends onto the middle of the plastic sheet securely, so that it can be pulled without coming off.

In summary...
This experiment cleverly illustrates how we breathe with simple household objects. When the diaphragm contracts in our bodies, air is able to enter the lungs due to the extra room this creates. When you exhale however, the diaphragm relaxes, forcing air out of your lungs. This is shown when you pull down and push up on the model's plastic sheet.

NEXT ISSUE
- How to split water
- How to build your own solar oven

A DIY chromatography test

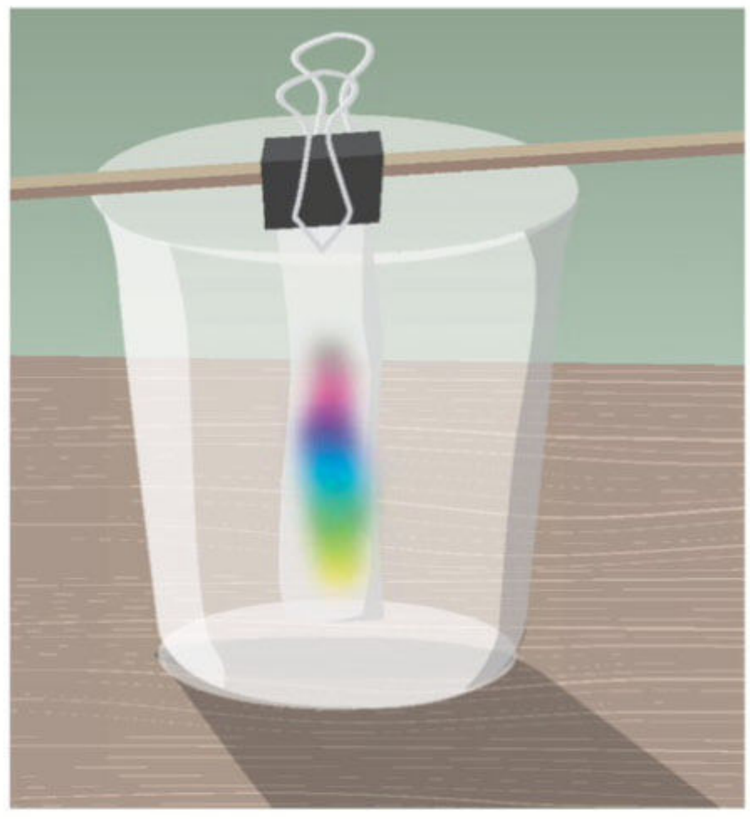
Find out how to separate inks into their different coloured components

1 Prepare your test strips

The first step for any chromatography test requires the test strips to be prepared. Cut some filter paper into strips, 1.3 centimetres (0.5 inches) wide. The length of the strips is dependent on the height of your cup, so make sure you cut them accordingly. Take your test pens and draw large dots 1.3 centimetres (0.5 inches) from the bottom of the strips, making sure you only use one pen per strip.

2 Mount your test strips

Take a wooden stirrer and secure the test strips to it, so that when the stirrer is rested across the top of your cup, the strips will hang down into it. There are a number of ways of attaching the strips to the stirrer, the best way is by making use of a bulldog clip. However, taping the strips to the stirrer will also work just as well. If you don't have a stirrer to hand, a pencil or pen will do.



3 Add your solvent

Now add the solvent, which travels up the filter paper and separates the inks. Pour some water into each cup so that the water just about touches the bottom of each test strip. If the test dots become submerged they will separate out without travelling up the paper. Leave the strips hanging in the water until the inks have separated and the different colours have nearly travelled the length of each strip.

In summary...

As water moves up the filter paper it carries certain colours with it. Some colours move further up the paper than others due to differences in their solubilities. In today's laboratories, chromatography is one of the most widely used analytical techniques. Different forms of chromatography are used to test blood and alcohol in forensics and are also used to separate out food dyes.

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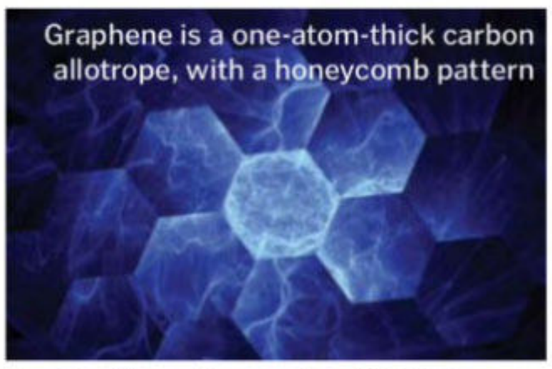
Letter of the Month

The science of crying

Dear **HIW**,
I really like your magazine, particularly how the subjects and articles change every month, this means that I can never get bored! Apart from talking about how amazing your magazine is (which I could do all day) I have a question to ask. Why do we cry? As far as I can see, crying doesn't help humans at all; in fact, when we're sad crying seems to make everything feel worse! Please could you answer my question?
Thanks
Owen Neill (aged 12)


Tears cascade down our faces when they overflow from our lacrimal drainage system

Although crying is often viewed as an embarrassing display of emotion, it does actually serve a purpose. Some experts argue that shedding tears is partly a survival mechanism. It signals that something needs to be addressed, whether you are frustrated, overwhelmed or just trying to get some someone's attention. One study suggests that it might even function to show vulnerability or submission to an attacker. Sobbing may also work to solidify relationships between those who share the experience, bringing them closer together, while others may use a strategic sniffle to manipulate others! Many argue that it actually makes us feel better, by releasing emotion that we've been storing up. Surprisingly, boohooing causes a number of physical changes in our bodies. Heart rate increases, breathing slows, we begin to sweat and a lump forms in our throats. Pass the tissues...


Graphene is a one-atom-thick carbon allotrope, with a honeycomb pattern

Graphene's applications

Dear **HIW**,
I was looking at an article about graphene and how it has many properties that could be beneficial to technology, and I wondered whether it would be in use in our devices anytime soon? I also wanted to know whether it's hard to make, and if it would be good for the environment to mass-produce it? I wondered this because many materials that are meant to be beneficial use a lot of energy to manufacture.

I have wondered about it for a while, and **HIW** are the best people to answer my questions!
Alex Palmer (aged 12)

Harder than diamond and 200 times harder than steel, graphene definitely has a range of potential applications in technology.

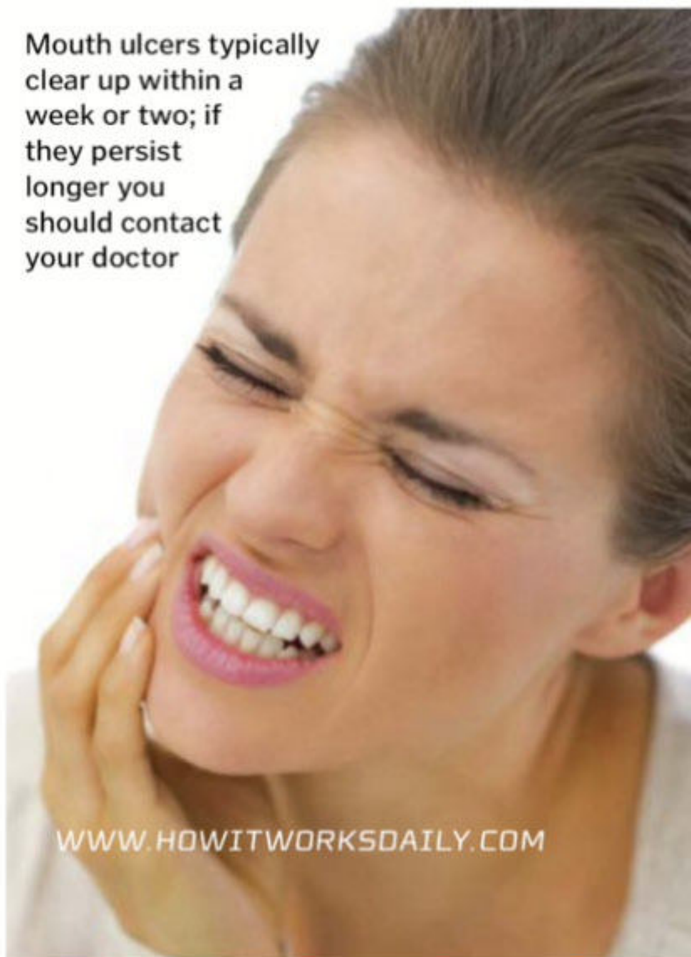
There are concerns over the potential release of graphene oxide during mass production. This compound has shown high mobility in surface water, and could impact multiple ecosystems if it was leaked into rivers or streams.

Recently, a PhD student developed a technique using methane and copper to produce endless sheets of graphene, which may be a solution to the high production costs. There are already graphene products on sale though, including sporting goods and components of electronic devices.

Why do we get mouth ulcers?

Dear **HIW**,
Can I just say **How It Works** is the best magazine out there! I always learn so many interesting new things; I loved reading about how we sleep in Issue 70. I already know that if we get too run-down and tired we are likely to get mouth ulcers. But what is an actual mouth ulcer? I would also like to know, what other things can cause them to pop up?
Thanks,
William Tucker (aged 14)

Mouth ulcers are really irritating, and can make the simplest tasks painful, such as eating, drinking or even talking. They are simply oval sores, which originally form as a small blister before opening into an ulcerated pit. A typical mouth ulcer will measure around 0.5 centimetres (0.2 inches) in diameter. They can be caused by injury to the inside of the mouth, such as accidentally biting your cheek while eating. An allergic reaction can also cause mouth ulcers to form, as can an autoimmune response to certain chemical agents.


Mouth ulcers typically clear up within a week or two; if they persist longer you should contact your doctor

If methylmercury accumulates in fish it can harm the predators that eat them, which could impact the food chain

"These bulbs contain less than one hundredth of the mercury in a typical thermometer"

What's inside eco bulbs?

Dear **HIW**,
I recently found out that 'eco bulbs' contain small amounts of mercury and mercury gas. Given that mercury has a negative impact on the environment, it seems slightly odd that companies are putting mercury into these sorts of bulbs. Do you have an idea why they do this?
Yours sincerely
Toby Green (aged 11)

It's hard to believe that supposedly 'green' light bulbs contain an ingredient that's harmful to the environment, but eco bulbs do in fact contain mercury. However, the amount of mercury they contain is less than the amount generated during the production of the extra electricity for a non-eco light bulb, so they are still a better choice for the environmentally conscious. These bulbs contain less than one hundredth of the mercury present in a typical thermometer, and should be recycled at a lamp recycler rather than a normal recycling plant.

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Awesome #SpiderSense coverage by **@HowItWorksmag**, Issue 72.

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Issue 72 is quite possibly the best issue of **@HowItWorksmag** ever! Love it!

@Rab19
@HowItWorksmag our #greatdayout is the Discovery Centre in Braintree, lots of walking, football and climbing/playing

@amylou152
@HowItWorksmag thank you so much for my prize & super quick delivery! Fantastic.

@stephenhawking
The greatest enemy of knowledge is not ignorance; it is the illusion of knowledge.

@ProfBrainCox
I'm going to make a cup of tea out of leaves fashioned from the remnants of long dead stars, reconstituted by the natural force of gravity.

@Matty_Brian
Just bought the latest issue. It's great for when I go away with work.

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Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
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Magazine team

Editor Jodie Tyley
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586274
Art Editor Andy Salter
Editor in Chief Dave Harfield
Features Editor Jo Stass
Research Editor Jackie Snowden
Staff Writer Philip Watts
Senior Art Editor Helen Harris
Assistant Designer Jo Smolaga
Photographer James Sheppard
Publishing Director Aaron Asadi
Head of Design Ross Andrews

Contributors
Sarah Bankes, Ed Crooks, Alexandra Cheung, Nicholas Forder, Alicea Francis, Shanna Freeman, James Hoare, Gemma Lavender, Siobhan Maguire, Adrian Mann, Laura Mears, Carrie Mok, Phil Morris, Alex Pang, Ceri Perkins, Lee Sibley, Luis Villazon, Tim Williamson

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Account Manager Jennifer Galvin
jennifer.galvin@imagine-publishing.co.uk
Account Manager Lee Mussell
lee.mussell@imagine-publishing.co.uk

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Circulation
Head of Circulation Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Finance
Finance Director Marco Peroni

Founder
Group Managing Director Damian Butt

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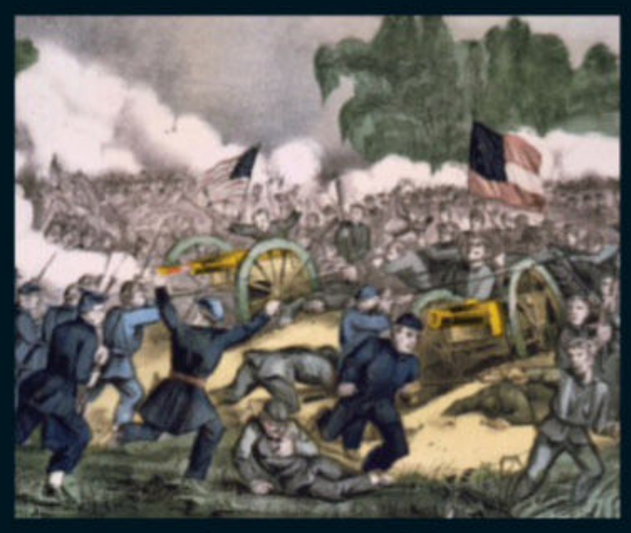

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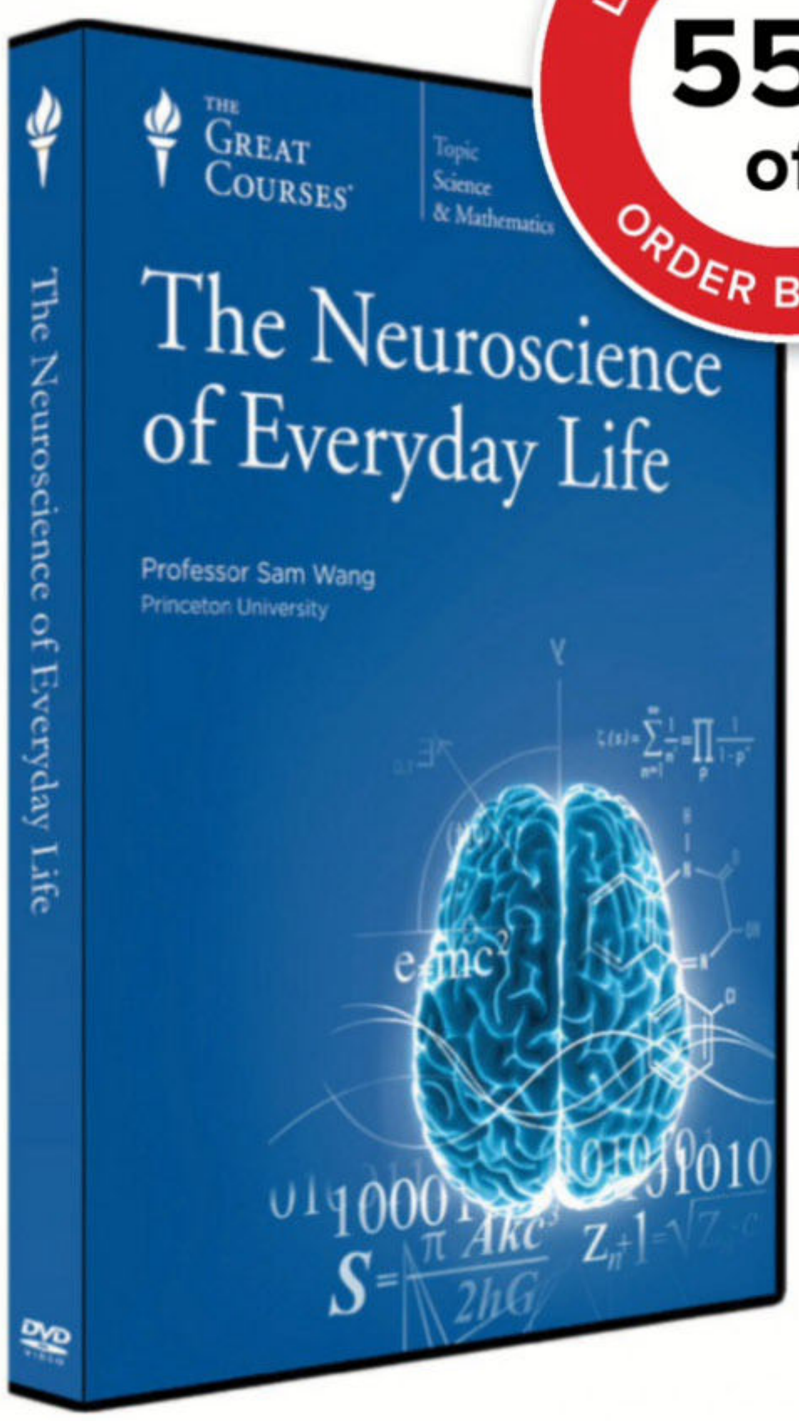

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